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MECHANICAL ENGINEERING

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The Engineer and Optimism

I tell you plainly that I believe that the engineer is going to have thrust upon him the task of guiding the thought of humanity in future years; the task of counteracting the effects of the despairing preachments of men of smaller preparation and of smaller vision. Naturally you are not going to be able to do this mechanically; you cannot convince before you believe. But your training prepares you for determining facts and for drawing reasonable conclusions therefrom. I do not think that you can be true to this training and at the same time despair of the progress and survival of the race.

(From How Long Shall We Live? By C. F. Hirshfeld, published in this issue, pp. 401–404)

MAY 1927

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS OF THIS ISSUE

How Long Shall We Live? *C. F. Hirshfeld* 401
Oxyacetylene-Welded Construction of a Large High-Pressure Storage Tank *H. E. Rockefeller* 405
Material Handling in the Port of New York *J. A. Jackson* 411
Tolerance and Allowance Charts for Metal Fits *T. F. Githens* 414
Surface Condensers in Steam Power Plants *J. A. Powell and H. J. Vetlesen* 417
The Training of Trades Apprentices (Discussion) 421
Organization—Railroad and Industrial (Discussion) 425
Opportunities for the Engineer in Industries *Arthur Scrivenor* 427
A Laboratory Study of Slag Erosion *S. J. McDowell* 429
Modern Fire Fighting in Oil Refineries *F. A. Epps* 431
The Boiler House in Oil Refineries *H. A. Ross* 435
Discussion of Papers Presented at Petroleum Session of Annual Meeting 437
Internal Friction in Solids *A. L. Kimball, Jr., and D. E. Lovell* 440
The Panama Canal Diesel-Engined Power Plant 445
Recent Developments in the Rolling of Sheet Steel 451
John E. Sweet an Early Advocate of Accuracy and Standardization 477
The Kansas City Regional Meeting 482

DEPARTMENTAL

Survey of Engineering Progress 455
Influence of Clearance on Specific Steam Consumption of Steam Engines and Especially of Locomotives; Short Abstracts of the Month
The Conference Table 468
Discussion of questions on Aeronautics, Fuels, Hydraulics, Railroads, Wood Industries, Etc.
Correspondence 470
The Design of Dished Heads of Pressure Vessels
A.S.M.E. Boiler Code Committee Work 471
The Engineering Index 489
Engineering and Industrial Standardization 472
Editorial 478
Coöperation Among Specialists; Expanding A.S.M.E. Publications; Better Teachers; The Mid-May Issue; Ask Me Another; Engineering Foundation Completes Twelfth Year of Service; Jesse M. Smith Dies
Notes on Engineering Education 483
A New Course in Fuel Engineering; A Summer School for Engineering Teachers; Industry and Education
Book Reviews and Library Notes 485

ADVERTISING

Display Advertisements 1
Hudson Avenue Generating Station Section 45
Professional Engineering Service Section 152
Classified List of Mechanical Engineering 157
Opportunity Advertisements 167
Alphabetical List of Advertisers 168

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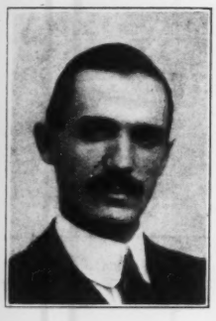

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MECHANICAL ENGINEERING

Volume 49 May, 1927 No. 5

How Long Shall We Live?

By C. F. HIRSHFELD,[1] DETROIT, MICH.

LET ME first remind you of the fact that this address is intended to be on an engineering subject and that I am speaking to you as an engineer. I plead guilty to having so worded the title as to have made misinterpretation possible, and further, I plead guilty to having done this intentionally. However, I hope that before I have finished you will all be willing to agree that the title does properly define my subject and that it is a proper subject for the consideration of engineers. I assure you that I have no intention of invading the field of medicine. No mere engineer would have the temerity to do so under any circumstances, much less at an institution so famed as this for its achievements in the medical field.

Engineering Largely a Method of Thought

But, lest you fail to understand what I regard as an engineer and as the field of engineering, I desire to give you certain definitions or, if you like, concepts before I speak on my subject. I regard an engineer as nothing more or less than a scientifically trained business man. Engineering, in the abstract, is largely only a method of thought. It has been referred to as that method which determines first the facts and then the logical and inevitable conclusions. Engineering, in the concrete, is a varying thing, depending upon the stage of development of our civilization and of our social structure. But at all times it is directed toward the use of nature's laws, or forces, or phenomena, as you like, for the benefit of the human race. The ways in which this is done and the specific ends to be achieved vary from year to year or generation to generation, but the overall results, the general end in view, is always the same.

If you give thought to this conception of engineering you must realize immediately that the engineer combines in a very curious and very unique way the characteristics of many other individuals. Thus, the real engineer would have the complete knowledge of business and possession of the business technique commonly attributed to the simple man of business. He should have a knowledge of financing and of economics approaching that of the man that we recognize as a banker or financier. And at the same time he should possess that peculiar appreciation of science and its possibilities of application which are possibly best exemplified by the medical man. The engineer must think scientifically and must apply science to the solution of our problems in the same way that the medical man does, but he must combine this with a complete understanding of the business, the economic, and financial aspects of the situation. This is why I call the engineer a scientifically trained business man.

If these rather sketchy definitions or explanations have succeeded in conveying to you my thoughts along these lines, we may now get to the subject in hand, namely, How Long Shall We Live? I do not here refer to the span of human life: I am satisfied to leave that problem in the much abler hands of the medical fraternity. I refer simply to the length of time that the human race shall continue to inhabit this earth of ours.

Until comparatively recent times little progress was made in attempting to find an answer to this problem. Then came a period during which the answer was sought in what one might call astronomical considerations, astronomical terms, and astronomical dimensions. But more recently we have started thinking in much shorter periods of time. We have begun to fear that our rapid consumption of this or that may ultimately prove to be the suicidal activity of a misguided humanity.

I may be an arrant optimist, but I cannot look over the history of humanity and study its achievements and then conjure up any woeful picture of humanity passing out of existence because of the depletion of this or that. To me it seems far more sensible to assume that future generations will be able to take care of themselves much more easily and much more completely than does this generation. To me it seems wrong to tax this generation in any way for the very doubtful advantage of future generations. Translated, this means that I do not believe in conservation of any sort that makes life now more expensive, because I am fully convinced that that which we thus save for a future generation will not be needed at that time. Do not misunderstand me. I do not believe in wasteful or careless utilization of natural resources. But I measure waste in these respects not by the best that is theoretically possible, but by what is economically justified.

To be sure, our prophets of evil do not always find their danger signals in the same place; but in a general way all these prophets follow the same mental path. They all recognize the depletion of something that now appears necessary to our existence and look with terror at the time when that particular form of depletion shall be so nearly complete as to make life, under present conditions, impossible. And there you have the essential bones of the argument.

Now before going further I should like to examine critically something that young engineers—and, in fact, college students in general—are inclined to accept more or less automatically, in so far as their respective mental capacities or attention to work permit. I refer to what we commonly call knowledge, or, more properly, human knowledge. As you pass through school and college you find such an abundant supply of knowledge ready for acquisition that you seldom give much thought to what this knowledge really is. It is fed to you much as food is fed to children, and if you are the average type of student, you accept it in much the same way.

Knowledge Nothing More Than a Record of Observed Facts

You will recognize without doubt that knowledge is entirely historical. That is, it is a record of observed facts, of human experiences and writings, and of human thought. If you delve deeper you will discover that, in so far as facts are concerned, human knowledge is nothing more than a group of records of what transpired under given sets of circumstances.

What we call scientific knowledge falls in this class. It is basically nothing more than a record of what was found to happen under different sets of conditions. To be sure, such knowledge has been dressed up in pretty clothes by some, and others have speculated as to possibilities outside the various scopes of investigation or even the various fields of investigation. But that which we actually know is only that which has been observed.

Now note, if you please, one of the curious limitations of the human brain. We record what happened under a given set of conditions, but until we try the same thing under another set of conditions we cannot say whether it will happen under such

[1] Chief of Research Department, Detroit Edison Company. Mem. A.S.M.E.

Lecture on Engineering Practice delivered at the School of Engineering, Johns Hopkins University, Baltimore, Md., April 28, 1926.

circumstances at all, or whether it will happen, but in a different way. Moreover we are exceedingly fond of fooling ourselves into believing that we know more than we do. This is generally done by giving names to things, as though naming them explained them.

To use a very homely example, let us take the thing that we call gravitational attraction. We observed long ago that small objects near the earth's surface tended to approach that surface if permitted to do so. We actually discovered the laws expressing the attractive force and those controlling the rate of approach. We can express such laws in very exact fashion and we can use them in ballistic and numerous other calculations. We went even further. We assumed this sort of attraction between material bodies to be a universally existing force, and determined the necessary results of its universal operation. By applying these laws with others to various heavenly bodies, we found that we could explain and predict the time movements and paths of these bodies very accurately. This peculiar, universal force we called gravitation, and then many of us sat back satisfied with our tremendous knowledge. But what is gravitation? Can you find a definition that does not merely run in a circle by defining it as that force which causes particles of matter or material substances to tend to approach each other? In other words, the force that causes such bodies to approach or tend to approach each other is gravitation, and gravitation in turn is the force that does this thing. It is a fine definition for a thinking man to be satisfied with when you stop to think of it, is it not?

If we were perfectly frank, we should admit that we do not know what gravitation is; basically, we do not know. We know of its effects under certain observed or tested conditions, and that is all. If you could imagine some condition under which the action of gravitation had not been tested in some way, you would also discover that you could not say what the action of gravitation would be until you tested under those conditions. My example is somewhat unfortunate in that the effects of gravitation happen to have been tested under so many different conditions that it is exceedingly difficult for one to imagine an untried combination.

Possibly an example from a different field will serve my purpose better. You all know of the spectrum and how different elements can be identified by means of characteristic lines in the spectrum. The positions of these lines must be found experimentally. Having been so found, we may use this knowledge advantageously, but we do not explain the phenomenon in any basic way. If we could predict the positions of these lines from known properties of the elements, such as atomic or molecular arrangement or something of that sort, our knowledge might be basic or more nearly basic. We shall not know which until we achieve this possibility.

PRESENT KNOWLEDGE NOT BASIC

We may generalize by saying that we have now no basic knowledge. It is hard on our pride to admit it, but the fact is that we do not. It is not beyond belief that some day we shall have such knowledge. Some of the work now being done in physics and chemistry and mathematics rather indicates that we shall, but we are still far from it.

For the time being, therefore, every engineer should refuse to fool himself. He should recognize plainly the unvarnished truth, namely, that this scientific knowledge of which we are so proud is nothing more than a partly codified statement of what things were observed to happen under various sets of conditions. The engineer, like the scientist, must be cold-bloodedly truthful with himself, even though it does hurt his pride or belittle his opinion of human accomplishment.

There is one further psychological trait of humanity to which I should like to refer. The average human brain has many peculiarities. By no means the least peculiar is a very clearly marked tendency to accept unquestioningly the developments of the past, but at the same time to question the possibilities of proportionate developments in the future. Let me illustrate by just one example. In my own work I am primarily concerned with the generation and use of electricity. During the past twenty years the quantity of coal required to produce a unit of electrical energy has, roughly speaking, been cut to one-third. If you will take the trouble to consult the technical literature of this particular art, you will discover that in almost every year of that twenty-year period, authors of articles dealing with power production have tacitly assumed that the then state of development represented practically the ultimate, unless some epoch-marking discovery could be made. Last month I attended a convention of men engaged in the generation and distribution of electricity and was asked categorically what we can do now toward cheapening our product, since further reduction in coal used per unit of output is impossible! I admit that I do not now see how we can reduce the coal requirements characteristic of our most efficient plants by more than about 20 per cent. But I refuse to assume that by the time we have availed ourselves of this possibility we shall not have already discovered practical means of traveling further along the same general path.

This example is but one of many that I could give you if time permitted. I hope that it may suffice to illustrate my point, namely, that we all find it exceedingly difficult to project ourselves and our activities forward mentally. In fact, speaking in general terms, it cannot be done.

DIFFICULTY OF ANTICIPATING DEVELOPMENTS OF FUTURE

I should like to impress upon you this curious psychological trait, this mental limitation, if you like, because its existence is really responsible for a great deal of misguided effort and unnecessary solicitude. It seems to me ridiculous that, when we have the history of the human race and its activities and achievements spread out before us like an unrolled scroll and can read thereon this never-varying tendency to consider any given stage of development as the ultimate, and in addition can see plainly the fact of continuing progress at an ever-increasing rate, we should not at least be able to develop in ourselves sufficient faith to cause us to believe that such progress will continue, probably indefinitely. I do not expect that we can overcome our inability to project ourselves far into the future, but I see no reason why we cannot develop faith in the ability of successive generations to continue the developments of the past into the future.

You may well ask how all this concerns the engineer and how it concerns the particular subject of my address. It is vitally essential to both. You may never have given it thought, but it is a fact that the engineer's work deals largely with the future. He plans and he constructs, ordinarily, to meet future needs. He develops the art along lines which he believes will fit it to coming changes. If, for example, it is believed that wage rates are going up, the engineer develops methods or mechanisms for producing more product per man-hour. If it is believed that some material, such as wood, for example, is going to become too scarce and therefore too costly for certain purposes for which it has been used, he proceeds either to develop substitutes or to develop structures in which more readily available materials can be used advantageously. When he builds a central-station power plant he must estimate probable changes in coal price and labor wage over a long period of time: he must estimate rate of growth of population in a given area and also its distribution within that area; he must form some idea of the possibility of radical change in power-producing equipment and of the general character of the change so that his structure shall not prove incapable of adaptation, and so on.

You see, the engineer is always endeavoring to anticipate future developments, but, being human like the rest of humanity, he fails woefully in projecting his thought beyond the very immediate future. However, this necessity for always looking ahead, for always expecting changes and endeavoring to anticipate them, develops in the mind of an engineer a viewpoint which differs from that of a large part of humanity. Of all of the practically minded members of society he is probably best prepared to appreciate the possibility, aye, probability, of continued development, and his work is best adapted to engender faith in the continuing ability of humanity not only to care for itself but also to care for itself in more complete and more satisfying fashion.

However, even with this tremendous advantage, the engineer frequently proves incapable of viewing the future optimistically. In spite of the peculiar combination of practical method of thought and well-developed imagination that marks the true engineer,

most of us find it difficult to develop faith sufficient to overcome the dire results of our more materialistic, practical calculations. If this be so in the case of the engineer, how much more difficult for one less fortunately situated to view complacently the future of the race!

THE ENGINEER TO GUIDE THE THOUGHT OF HUMANITY IN FUTURE YEARS

I tell you plainly that I believe that the engineer is going to have thrust upon him the task of guiding the thought of humanity in future years: the task of counteracting the effects of the despairing preachments of men of smaller preparation and of smaller vision. Naturally you are not going to be able to do this mechanically; you cannot convince before you believe. But your training prepares you for determining facts and for drawing reasonable conclusions therefrom. I do not think that you can be true to this training and at the same time despair of the progress and survival of the race.

Let me suggest this line of thought to you. Place yourself back in the stone age when the most effective arrow heads and spear heads were laboriously chipped out of flint. Man's continued existence appeared to depend upon a continued supply of flint. And I am certain that if any one at that time had given thought to the matter he could have predicted when the depletion of the available supply must inevitably have spelled the end of human existence. And later, when the flint and steel served as the common means of producing fire for certain purposes, an equally logical sort of argument *in extremis* could have been produced. And yet how ridiculous these arguments would look to us today with our metallic weapons and instruments of all sorts, and with many different and much more convenient means available for producing fire!

Let us now look at the situation of the present day. Our papers and magazines and other publications have for many years contained authoritative articles demonstrating that the world's supply of petroleum is measurably limited and predicting most dire results following its exhaustion. One of the popular figures at the present day is effectively complete exhaustion in about twenty-five years. And please note that this is all predicated on the assumed contents of a few known fields; that no account is taken of the uncounted acres of unexplored lands and of the unknown contents of the lower strata of the earth's crust. But, assume if you like what I refuse to believe, namely, that a period of twenty-five years does measure approximately the time during which we shall practically exhaust our underground petroleum supply. After this is all gone we still have available mountains of oil-producing shale covering large areas in many of our states, and, in fact, all over the world. It is true that we cannot work this shale economically at the present time, but why should we be able to do so? What economic pressure exists to force us into the development of the necessary methods and equipment? As a matter of fact, it is estimated on fairly satisfactory evidence that petroleum products can be obtained from these deposits by present methods at prices within a few cents of those characteristic of the oil-well products. Does it seem unreasonable to suppose that at the time when we are forced to use these deposits, the products derived from them will be salable at prices that will fit the then existing economic situation?

Calculations made by various engineers and geologists indicate that after we have completely exhausted underground oil supplies, these mountains of oil shale will prove capable of supplying our needs for centuries. The estimates differ; some yield a few centuries, others a few thousand years.

If, now, you are obstinately logical, you may well remark, "Yes, even so, but they will also be exhausted some day, and then what?" I hardly dare pose as the prophet of future millenniums. However, I can tell you that we are now conducting experiments which have proved that it is possible not only to make petroleum products out of coal, but to actually convert practically all of the coal substance into petroleum products which you cannot differentiate from the best oil-well product of the present day. And, possibly fortunately, the poorer grades of coal which are least well adapted to meet our present needs appear to yield the best results with these new processes. Perhaps this will be the next step after we use up our underground supply or after we use up our shale supply. I do not profess to know, but I do know that we can see an economically available oil supply ahead of us for centuries if not for millenniums, and this in the face of the dire calamities predicted for some twenty-five years hence!

And to make the picture still more ridiculous, how do we know that we are going to want petroleum products twenty-five years hence or a century hence or a millennium hence? If one may judge from the past, we probably shall not.

You can quite properly say that I found at least part of my optimistic argument on the possibility of making such products from coal, and that this is a worthless argument since our coal resources have been proved to be inadequate to our future needs. They have been claimed to be so limited, but never so proved. We know of great numbers of coal beds which have not been included in such estimates because they have not been considered available for one reason or another. Moreover we have every reason to believe in the existence of tremendous beds that have not yet been discovered. Still, some day we must exhaust all the available coal supply, and what then? To me the question is rather how long before that time shall we have become independent of coal? I do not believe that we shall ever exhaust either the coal or petroleum supplies, because I firmly believe that long before we reach such a point we shall have found other and more economical methods of obtaining the necessary light, heat, and chemical products.

Let us consider another example. When I was an infant it was common practice to dump on the pile of mine waste, silver- and gold-bearing rock which was too poor to be worked by the methods then available but which is now considered exceedingly valuable ore. In fact, some of the dumps of those days, containing a small amount of such ore mixed with the practically worthless country rock, have been put through modern mills and have made fortunes for the workers.

When I was in college, copper ore had to assay a certain comparatively high value to be worth recovering. Since that time mountains of low-grade copper ore, assaying less in some cases than the tailings from old mills, have been and are being worked profitably. In fact, some of these low-grade properties threaten seriously the older, richer workings.

In each case it was comparatively easy to calculate when we must necessarily exhaust the available supply, but, in fact, we have kept right on increasing it at such rates that there are actually surpluses of each of these materials at the present time, with less prospect of exhaustion now than then.

RESEARCH AND INGENUITY NOT ONLY SUFFICIENT TO KEEP DISCOVERIES ABREAST OF NEEDS, BUT CAPABLE OF ANTICIPATING THEM

It would be possible to go on in this vein for hours, but time does not permit. What I want to impress upon you here is the rapid progress that we actually make and the resultant rapid change in the significance of all apparent limitations to our further development. When you give real study and thought to this part of our history, you must inevitably conclude that research and ingenuity have proved not only sufficient to keep our discoveries abreast of our needs, but also capable of even anticipating our needs. It has frequently happened, particularly in the past few decades, that we have developed needs as the result of discoveries capable of satisfying such needs.

Remember that scientists and mathematicians are extending the borders of our knowledge ever more rapidly. As a result each day brings to us new knowledge which, in the hands of more practically minded men, such as industrialists and engineers, is put to work for us in one way or another. The time has already arrived when it is exceedingly difficult for one individual to keep moderately well informed with respect to the discoveries of the day; and, in terms of what is to be expected in the future, we have hardly started along this line of progress.

As I study, from the viewpoint of the engineer, the history of the human race and the activities now going on, I am constantly impressed by the way in which humanity has been able to better its condition continuously, and the way in which economic pressure has always brought about a proper and satisfactory adjustment.

Certain lessons stand out very prominently in my mind, and they lead me to a very simple, pragmatic type of philosophy which has the great advantage of being thoroughly optimistic.

I note (1) that human discovery and invention have always been ahead of human need; in fact, need has frequently followed from discovery.

I note (2) that humanity has always attempted to interpret the future in terms of the present and has practically always failed dismally.

I note (3) that none of the dire results predicted as inevitably bound to follow the excessive depletion of this or that natural resource, has ever materialized in such a way that a thoroughly satisfactory readjustment was not possible and generally profitable.

I note (4) that man's activities up to the present time have been largely destructive in the sense that he has used for his purposes, and destroyed in the using, certain natural materials or resources. But, recently he has started on a new trail; instead of always breaking down and wasting, he is now sometimes building up. He has started synthesis in a fairly large way, and there is every promise that this movement will increase.

In connection with this last observation, you may quite properly remark that nothing can be synthesized without destroying in the process those things from which it is made. This is perfectly true, but I am looking at the matter in a slightly different light. I am bringing in both the economic value of the raw materials and the frame of mind involved. We are beginning to substitute for products obtained more or less laboriously and at high cost from animal or vegetable extractions, similar or like products made comparatively cheaply from cheap or even waste raw materials. The mental aspect is quite changed; we may describe it by saying that we are now thinking seriously of building up instead of breaking down, and of utilizing to the utmost instead of merely skimming the cream.

We are coming to regard the total quantity of material in that part of the universe available to us somewhat in the same way that we do the contents of the bottles on the shelves in our chemical laboratories; that is, as materials which we can recombine time after time, in this way and that, to meet the needs of the moment. And I am sure that we shall go much further in this direction than any of us has yet dared to dream.

Now those of you who have listened understandingly and have given thought to what I have said will probably have realized the fact that I have left out of consideration one very important item. You have all learned, in one way or another, that at least that part of the universe in which we are particularly interested is gradually running down. It has been likened by some to a clock which was wound up at the start and has been running down ever since. Others speak in terms of degradation of energy. But, whatever the words used or the picture painted, the idea is the same. We are moving gradually but surely to the time when we shall reach a dead level, in so far as energy is concerned, and when that time arrives we shall be powerless to effect any changes in the materials of nature. I admit frankly that we dare not overlook this aspect of the situation. We may not predicate continued existence on our ability to juggle material substances to suit our needs unless we are to have available the energy with which to do the juggling.

The greater part of the energy that we now use is that coming from the sun at the present time, or that which came from the sun in recent times, or that which came from the sun in more distant times, and we are using up the storage of bygone ages much more rapidly than we now know how to replace it from our present daily supply. Obviously if such a process is continued long enough and if the sun is gradually cooling down, as we have good reason to believe, we must ultimately reach the dead level that has been predicted, unless we do in fact find some other source of energy. It has been suggested that this new source is to be found within the molecule or the atom, those miniature astronomical systems which we now know to contain in bound or latent form most unbelievably large quantities of energy. It remains to be seen whether this is to be the solution or whether the solution will be something much more prosaic or something still less suspected at the present time. Judged by our present rates of consumption and the supplies of latent energy in sight and suspected, the human race might have to consider this problem seriously some thousands of years hence. Certainly the progress made in the last century, and particularly in the last two decades, gives at least a promise of a satisfactory solution within a few thousand years.

Humanity Not to Pass Out of Existence Because of the Depletion of Any Given Natural Resource

I may be an arrant optimist, but I cannot look over the history of humanity and study its achievements and then conjure up any woeful picture of humanity passing out of existence because of the depletion of this or that. To me it seems far more sensible to assume that future generations will be able to take care of themselves much more easily and much more completely than does this generation. To me it seems wrong to tax this generation in any way for the very doubtful advantage of future generations. Translated, this means that I do not believe in conservation of any sort that makes life now more expensive, because I am fully convinced that that which we thus save for a future generation will not be needed at that time. Do not misunderstand me. I do not believe in wasteful or careless utilization of natural resources. But I measure waste in these respects not by the best that is theoretically possible, but by what is economically justified. Thus, it is possible to build a power plant that will produce a kilowatt-hour for an expenditure of one pound of coal or even less. The grand average for the country is probably nearer two to two and one-half pounds or even more. We are undoubtedly wasting coal in one sense in operating the older and more inefficient plants. But the waste in an economic sense would be far greater if we scrapped all these old plants immediately and built most efficient modern plants in their places. Some of the more theoretically minded conservationists would have us do that very sort of thing in order to conserve fuel for very distant generations living under entirely different physical and economic conditions and possibly having no use for fuel of any sort.

You who are engineers are going to meet these two divergent points of view throughout your work. I am satisfied that there is only one correct answer, and that is that we must do at any time that which appears economically correct at that time, with due consideration of what can be reasonably predicted for the next few years. I am satisfied that it is wrong to waste too much thought on distant generations and that it is wrong to make the present generation pay more than necessary in order to conserve for the distant future.

You may call this a hard point of view. I call it a practical one. I have told you that my philosophy is pragmatic. I must insist that the course that I advocate has worked in the past and that it does not require an exaggerated faith in human ability to lead one to believe that it will work in the future.

Economic Considerations, Not Sentiment, Should Form the Basis for Engineering Decisions

I should like to urge upon you young engineers, who are just starting life, two things:

First, that you make economic considerations and not sentiment the basis for your engineering decisions; and

Second, that as members of the respective communities in which you may happen to work and live, you do what you can to make others use the same yardstick instead of morbid sentimentalism.

Once more, please do not misunderstand me. I have a reasonable modicum of sentiment in my make-up. I realize the tremendous place that it occupies in human relations, and I should be the last to eliminate sentiment from the daily life of the engineer or any other individual. But, in so far as we can now see, we must base engineering decisions on scientific and economic principles, first going as far as we can see, and then seeing how much farther we can go.

And now, if I may return for a moment to the title that I gave to this rather rambling discussion, when we look at things from an engineer's point of view are we not justified in assuming that the human race will undoubtedly continue to live for so long a time that nothing that we can now do will make any material difference in the length of that period?

Oxyacetylene-Welded Construction of a Large High-Pressure Storage Tank

Design of Tank—Selection of Material—Checking of Welders—Welding Longitudinal and Girth Seams—Design of New Manhole Reinforcing Ring and Its Welding to the Manhead

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THE recent completion of a large ethylene storage tank, constructed for the Carbide and Carbon Chemicals Corporation, marks another decided step in the advancement of oxyacetylene welding in the pressure-vessel field. This tank, constructed of 1 1/8-in. shell plate and 5 ft. in diameter by 43 ft. long, is now operating under the designed 300 lb. working pressure with complete satisfaction to the purchaser.

Before taking up a discussion of the design or method of welding this tank, it may be well to look backward a few years in order to indicate the gradual development of commercial welding in this field of application. About three years ago the Carbide and Carbon Chemicals Corporation was confronted with the problem of providing storage capacity for a gas at 125 lb. pressure, it being essential that the containers be *absolutely* leakproof. The advice of The Linde Air Products Company was solicited, and it being decided that the oxyacetylene process was the logical one to be used, the contract was placed with a tank fabricator with the understanding that Linde supervision be provided.

In the design and construction of these tanks, a definite procedure was worked out with the fabricator to insure satisfactory results. The factors involved in this procedure were: (*a*) correctly designing the joints, (*b*) selecting material of good welding quality, (*c*) determining the ability and knowledge of the welding operators, (*d*) properly preparing the plates for welding, (*e*) applying approved welding technique, and (*f*) testing the completed joints.

Since the fabricators had never welded plate as heavy as required in these tanks, it was agreed to limit the design fiber stress to 7000 lb. per sq. in. so that there would be no question as to the safety of the welded joints. On this basis of design a shell thickness of 3/4 in. was required, the specifications calling for tanks 7 ft. in diameter and 35 ft. long. The results obtained on the first three tanks, however, convinced both the fabricator and the purchaser that the original design fiber stress was too low and it was consequently increased to 8000 lb. per sq. in. in designing the remainder of the tanks needed at that time. No discussion of the other factors involved will be made, as detailed consideration will be given to them in the subsequent description of the ethylene-tank construction.

In the early part of 1926 a demand arose for the storage of a considerable amount of gas at 300 lb. pressure. Although the tank requirements necessitated the use of heavier plate than had ever before been commercially gas welded in tank fabrication, the Carbide and Carbon Chemicals Corporation, having had such entire satisfaction in the operation of the tanks previously constructed, did not hesitate in specifying oxyacetylene welding.

Design of Tank

The storage requirements called for a tank 5 ft. in diameter by 43 ft. in length. The design adopted is shown in Fig. 1 of Mr. Greene's paper. The 1 1/8-in. shell thickness was based on a design fiber stress of 8000 lb. per sq. in., the same as employed in the preceding construction. In designing the heads, however, several changes were made in the layout previously used. It had been found from strain-gage measurements taken during the tests of the last tanks that the metal exceeded the yield point on the head knuckles and about the manhole opening, a standard knuckle radius of about 2 1/2 in. and a straight flange length of 3 in. having been used. To provide a more satisfactory knuckle design, a 6-in. outside radius and a straight flange or skirt 6 in. in length were specified. (It will be noted that the minimum inside knuckle radius by the A.S.M.E. Unfired Pressure Vessel Code would be 1.8 in.) Otherwise the heads were designed in accordance with the A.S.M.E. Unfired Pressure Vessel Code, except that a design stress of 9000 lb. per sq. in. was used instead of 10,000 lb. as is allowed on plate of the strength specified.

In an attempt to cut down the stresses about the manhole opening, the manhole reinforcing ring was also designed considerably stronger than specified in the Code, a 1 1/2-in. saddle plate being used when one 1 1/4 in. in thickness would have met the Code requirements.

It will be noted that the design of the welded joints for all longitudinal and girth seams is of the double-V butt type. The included angle of V was specified to be not less than 90 deg. and the reinforcement not less than 3/16 in. on each side of the double-V, or a total reinforcement of about 30 per cent. The ultimate strength of this type of joint, when properly executed, considerably exceeds the requirement of a factor of safety of five based on the comparatively low design fiber stress used in this instance.

The fillet welds joining the manhole reinforcing ring and manhead were so designed that their shearing and tensile strengths were greater than the tensile strength of the material removed from the head. (The unit shearing and tensile strengths of the weld metal were figured conservatively at 30,000 and 40,000 lb. per sq. in., respectively.) The welded connections were also designed to permit of satisfactory welding and to provide ample area of weld metal.

Another point in the design which should be noted is the location of the welded seams. It will be observed that the longitudinal seams are staggered 180 deg. Where two longitudinal seams are used per course the seams should be staggered 90 deg., and when three seams per course are used, the angle between adjoining welds should be 60 deg.

Selection of Material

In order to insure the quality of the material used, firebox steel with a maximum carbon content of 0.20 per cent and a minimum tensile strength of 50,000 lb. per sq. in. was specified. The specifications also called for the use of nickel-steel welding wire conforming to the American Welding Society specifications.

The following is a copy of the mill report on the steel used:

	Chemical Analysis				Physical Properties		
Size of Plate, In.	C	Mn	P	S	Yield point, lb. per sq. in.	Tensile strength, lb. per. sq. in.	Elongation in 8 in., per cent
1 1/4 × 82 1/2 diam.	0.18	0.42	0.011	0.030	36,500	57,440 58,130	30.25
1 1/8 × 82 1/2 diam.	0.18	0.46	0.010	0.027	33,540	52,400 54,130	29.50
	0.18	0.35	0.013	0.033	34,140	50,430 52,320	31.00
	0.18	0.35	0.013	0.035	30,850	52,970 53,480	32.50
1 1/8 × 96 1/4 × 198 3/8	0.18	0.35	0.013	0.035	32,270	51,060 52,730	30.75
	0.18	0.35	0.013	0.033	33,650	51,160 53,650	29.75
	0.18	0.35	0.013	0.033	34,420	52,050 53,140	31.50

Check of the Welders

As a check on their ability to meet the welding specifications, each operator was required to pass a qualification test. The test included the welding together of two sections of 1 1/8-in. plate, beveled and set up in accordance with the specifications. Three standard coupons were cut from each weld specimen and pulled in a tensile testing machine. The requirement for passing this qualification test was that none of the coupons should show an ultimate strength of less than 45,000 lb. per sq. in. of plate section.

None of the operators engaged in the plant at which the tank was

[1] Linde Air Products Company.

Presented at a joint meeting of the Metropolitan Section and Machine-Shop Practice Division of the A.S.M.E. with the New York Section of the American Welding Society, New York, January 4, 1927.

fabricated had ever welded plate above $^3/_4$ in. in thickness. With a small amount of practice under proper supervision, however, each of the welders easily passed the qualification test. The following table indicates the results of the tensile tests.

Welder	Specimen	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Fracture
A	1	31,760	46,300	Edge of weld
A	2	35,000	54,400	In plate
A	3	36,200	53,300	In plate
B	1	30,600	47,600	In weld
B	2	35,420	54,200	In plate
B	3	35,400	53,500	In plate 1 in. from weld
C	1	33,000	50,700[1]	In plate
C	2	32,600	54,000	In plate $1^1/_2$ in. from weld
C	3	31,200	50,200[1]	In plate 2 in. from weld
C	4	32,500	51,300	In weld

[1] Reinforcement ground off.

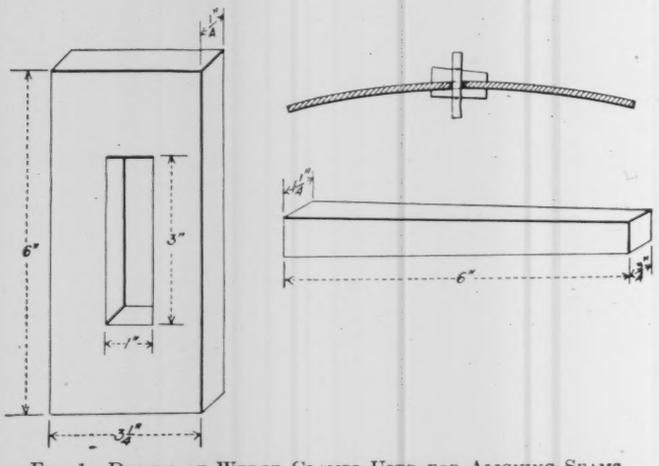

Fig. 1 Design of Wedge Clamps Used for Aligning Seams

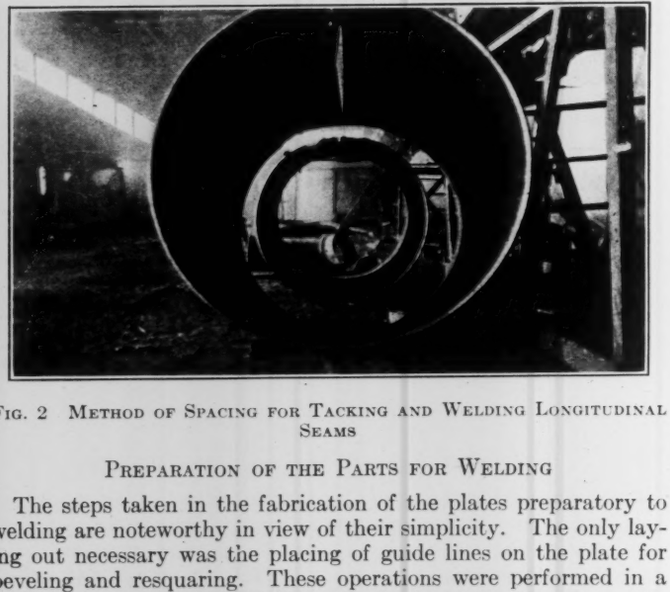

Fig. 2 Method of Spacing for Tacking and Welding Longitudinal Seams

Preparation of the Parts for Welding

The steps taken in the fabrication of the plates preparatory to welding are noteworthy in view of their simplicity. The only laying out necessary was the placing of guide lines on the plate for beveling and resquaring. These operations were performed in a single set-up on the plate planer. To eliminate the flat spots on the plate ends, the edges of the plate were set to the proper curvature before being placed in the rolls. This operation was accomplished in a sectional press, the plate ends being heated before being formed. Although on the plate thicknesses previously welded the elimination of the flat spots had been accomplished by the use of jigs when lining up the girth seams, it was thought inadvisable to rely on this method of obtaining the proper curvature because of the stiffness of the heavy shell plate used in this instance.

Following the rolling operation, the abutting longitudinal seams were fastened by means of wedge clamps and then moved to the portion of the shop where the welding was to be done. The design of the wedge clamps employed is shown in Fig. 1. Prior to welding each of the longitudinal seams, one end was tack-welded and the other separated the required distance to provide for contraction. For tacking, a spacing of $^1/_8$ in. was used, and a tack weld made about 1 in. in length. When necessary a turnbuckle was employed to obtain the desired spacing. The spacing of the seam for welding was secured by inserting a wedge at the open end and spreading the plate edges about two inches at this point. This provided an allowance for contraction during the welding of $^1/_4$ in. to the foot. Fig. 2 illustrates the method of tacking and spacing. The course shown in the background is prepared for tacking, and the one in the foreground is spaced and ready for welding.

Welding Longitudinal Seams

In joining the longitudinal seams, the welding of the outer V was accomplished first, being carried on without interruption from start to completion. Three operators alternated on two seams so as to provide a 15-minute rest period after each half-hour of welding.

The method of allowing for the contraction of the seam during welding proved entirely satisfactory. After the weld had progressed a short distance, the wedge clamps were removed and the contraction of the seam controlled by the use of a wedge and a "C" clamp inserted at the open end of the seam. The manner in which the "C" clamp was employed is indicated in Fig. 3. The wedge was manipulated so as to maintain a spacing of about $^5/_{16}$ in. between the plate edges a foot ahead of the point of welding. By doing this a constant spacing of about $^1/_{16}$ in. was secured at the point of welding. This provided a sufficient opening to secure thorough

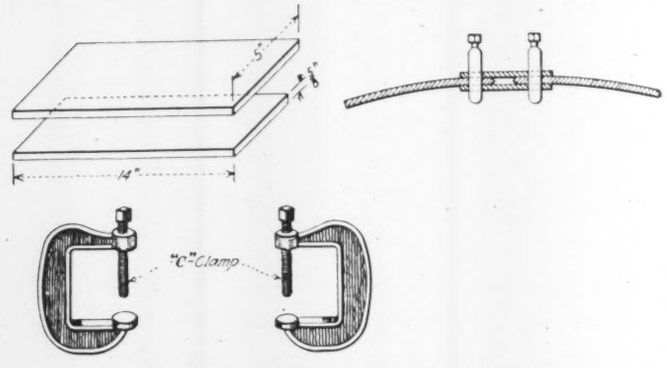

Fig. 3 Design and Method of Using "C" Clamp

penetration easily without slowing up the welding operation, as occurs when too wide a separation exists at the bottom of the V. Preheating from the inside of the seam by the use of an oil torch was tried but soon discontinued. The improvised preheating arrangement, as shown in Fig. 4, was difficult to control and caused considerable discomfort to the welders. Therefore, when it was discovered that the outer V could be welded without preheating, this supplementary operation was eliminated. The course, as will be noted in Fig. 4, was tilted at an angle of about 15 deg. to facilitate the building up of the required weld reinforcement.

After completing the seam from the outside, the inner V was chipped out to remove the oxide and excess metal which had penetrated to the inside of the seam without becoming thoroughly fused with the base metal. In welding the inner V it was found necessary to resort to preheating since the size of tip used, a No. 15 Oxweld, did not give sufficient heat to fuse the base metal with reasonable speed after the outer V weld had been made. An oil burner was used as the preheating medium, it being aligned in such a way as to direct the flame on the outside of the seam about 4 in. ahead of the point of welding. A forced draft supplied from the shop compressed-air lines provided sufficient ventilation to carry off the heat radiating from the weld, making it possible to carry on the welding without interruption or inconvenience to the welders. Fig. 5 indicates the manner in which the inner V of the longitudinal seams was welded.

Reforming and Annealing

All the longitudinal seams were welded essentially in the manner indicated above. Upon completing the welding of the fifth course, they were checked for roundness and then annealed to eliminate any locked up stresses. Where necessary, the ends of the courses

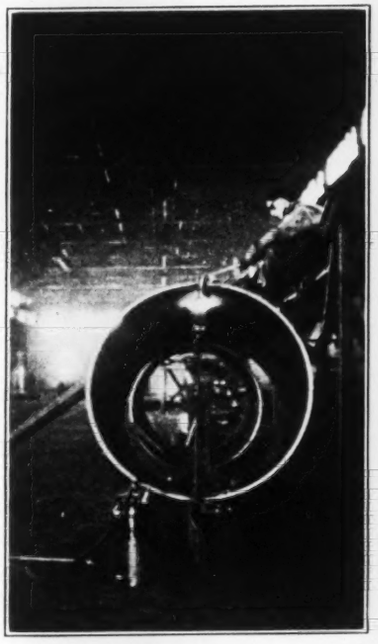

Fig. 4 Preheating Arrangement Tried in Preheating Out V of Longitudinal Seams. Note How Seam Was Tilted to Facilitate Building Up of Weld Reinforcement

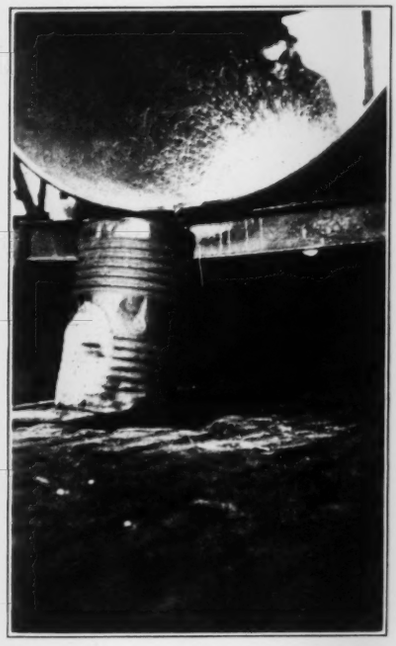

Fig. 5 Welding Inner V of Longitudinal Seams. Note Method of Preheating with Oil Torch

Fig. 6 Method of Securing Desired Spacing and Alignment of Girth Seams. Note Tack Weld

were heated and hammered to secure the required roundness. The annealing was accomplished by heating the entire length of the seam for a distance of about 1 ft. on each side of the weld to a uniform dull red. The course was then removed from the fire, the heated section covered with dry ashes and the seam allowed to cool slowly.

These operations had not been employed on any of the tanks previously constructed as our experience had justified the decision that annealing of welded seams in general is unnecessary. In this instance, however, these precautionary measures were taken because of the heavy plate used.

Lining Up and Tacking Girth Seams

The lining up of the girth seams was accomplished by the use of the same wedge clamps previously mentioned in connection with the lining up of the longitudinal seams and illustrated in Fig. 1. The courses to be joined were first set up on rollers and the adjoining longitudinally welded seams staggered as required. The wedge clamps were then inserted at equidistant points of about 8 in. along the entire seam. A spacing of $\frac{1}{2}$ in. between the abutting plate edges was employed, and the wedge clamps manipulated until the seam was within $\frac{1}{4}$ in. of true alignment at all points on its circumference.

It was then tack-welded at four points. Two welders working at points 180 deg. apart, one on the top welding on the outer V and the other within the shell welding on the inner V, made two tack welds simultaneously. The shell was then turned through 90 deg. and the other two tack welds made. Each tack weld was about four inches in length and without reinforcement. Fig. 6 illustrates the manner in which the wedge clamps were used and the tack welds made.

Welding Girth Seams

The actual welding of the girth seams was accomplished in much the same manner as were the longitudinal seams. With the exception of one seam, the outer V was welded first without preheating and the inner V next, using the oil torch for preheating the seam from the outside. The manner in which the oil torch was used is indicated in Figs. 7 and 8.

Instead of tilting the course, as was done on the longitudinal seams to simplify the building up of the required reinforcement, the welding puddle was kept at an angle of from 10 to 15 deg. off center by turning the shell on the rollers as required. The welder, furthermore, instead of moving along the seam as it was welded, remained in one position and had the tank turned to suit his convenience.

Fig. 7 Preheating Girth Seam While Welding Inner V

The method of providing for contraction was also considerably different from that employed on the longitudinal seams. In the latter case, it will be recalled that the seam was spread at the open end and allowed to contract as the weld progressed. In setting up the girth seams, however, the abutting plate edges were spaced equidistantly along the entire seam and wedge clamps inserted at small intervals to retard the movement of the plate edges during welding. The four tack welds were made to prevent any undue contraction at one point and expansion at another.

It would appear that this method of providing for con-

Fig. 8 Preheating Head Seam While Welding Inner V

traction by preventing it would tend to lock up the contraction stresses and thus give trouble. Since, however, a spacing of $1/2$ in. was provided before tacking, the weld was allowed to contract in small increments and the effect of this contraction was largely prevented from being transmitted to the unwelded portion of the seam because of the wedge clamps and tack welds used. This method therefore prevented the locked-up stresses from building up in such magnitude as to give any trouble. In welding the second side of the double V, furthermore, the locked-up stresses caused by welding the first side were largely dissipated through the reheating of the welded area both by the oil torch and the oxyacetylene blowpipe.

The application of this method was carried on in the following manner. The wedge clamps were removed for a distance of about 18 in. from the starting point of the weld. As the weld progressed, other wedge clamps were removed in such a way as to maintain a spacing of about $1/4$ in., a foot ahead of the point of welding. To do this it was sometimes necessary to weld up to within about 4 in. of a wedge clamp before removing it, and the upright portion of the clamp, in this case acting as a wedge, had to be removed by cutting it out with the blowpipe. As the weld approached one of the tacks, however, the spacing between the plate edges naturally increased, and it was therefore a comparatively simple matter to control the contraction.

Following this method of procedure little difficulty was encountered in welding the six girth seams. At no point did the plate edges overlap, and for the greatest portion of the seams, the spacing between the plate edges varied from $1/16$ to $3/16$ in. Figs. 9 and 10 illustrate the manner in which the wedge clamps were used to maintain the proper spacing. The thorough penetration of the seam is also made clear in these views.

FIGS. 9 AND 10 METHOD OF MAINTAINING PROPER SPACING OF GIRTH SEAMS DURING WELDING OF OUTER V. NOTE PENETRATION BEING SECURED

FIG. 11

WELDING SADDLE PLATE TO MANHEAD

In welding the saddle plate to the manhead, the two pieces were first tack-welded at the four corners of the outer flange of the saddle plate. This was accomplished while the head was in a horizontal position and after the saddle plate had been properly aligned with respect to the hole in the manhead.

After tacking, the manhead was tilted at an angle of about 20 deg. and the welding started at a point adjacent to one of the tack welds. The oil torch was used to provide additional heat in the vicinity of the point being welded. The welding progressed until the second tack weld was reached. The head was then turned, the welding started in the opposite direction and continued until the seam was completed. This change in direction of welding was pursued in order to reduce the locked-up stresses and minimize the tendency of the saddle plate to lift up from the head.

The manner in which the seam was heated and welded is indicated in Figs. 11 and 12.

The seam having been completed from the inside, the head was turned over and the outside weld made. This seam was welded continuously in one direction but otherwise the procedure followed was the same as employed on the inner seam.

FIG. 12

FIGS. 11 AND 12 WELDING SADDLE PLATE TO MANHEAD. NOTE METHOD OF PREHEATING

PROVIDING VENTILATION

The sequence followed in joining of the shell sections and the heads was such as to entail the minimum discomfort to the welders. It had been learned from previous experience in fabricating welded tanks, that as long as the cylindrical portion remained open at both ends, no trouble was encountered in keeping the welder cool and providing ample ventilation. In welding the inner V of the head seams and particularly in making the last inner V weld, however, even with the best ventilation system which could be provided with the available equipment, the welders had been subject to some discomfort from the heat. In the construction of the ethylene tank, therefore, it was decided to weld three courses together and then to join the heads to the remaining courses before attaching them to the shell. This sequence worked out very satisfactorily with the improved ventilation system we were able to employ. Figs. 13 and 14 illustrate the methods used for ventilating the interior of the tank and drawing the heat away from the welders.

In welding the last seam, furthermore, contrary to the usual practice, the inner V weld was made first. This permitted the elimination of preheating when welding on the inside of the tank and also allowed part of the radiated heat to escape through the unwelded portion of the seam. The welding of the outer V of this seam was accomplished by the use of two welding blowpipes, one used as the preheating medium and the second for welding.

The welding of the nipples and other connections was carried on in accordance with regular accepted practice. Because of the considerable difference in thickness between the shell plate and pipe walls, however, the plate had to be preheated to a bright red before the blowpipe flame was allowed to impinge on the surface of the connection being welded.

FIG. 13 PROVIDING VENTILATION FOR OPERATOR WELDING MANHEAD TO FIRST COURSE

TEST OF TANK

On completion of the tank it was first given the regular hydrostatic test imposed on all welded pressure vessels previously constructed. This consisted in applying a pressure of 600 lb. (twice the designed working pressure) and hammering all the welded seams with a 10-lb. sledge. The pressure was then increased to 900 lb. (three times the designed working pressure). This is the limit to which all previously constructed tanks were tested and is the test which is called for on welded vessels in the A.S.M.E. Unfired Pressure Vessel Code. (It might be pointed out here that since the A.S.M.E. Unfired Pressure Vessel Code allows a design fiber stress of only 5600 lb. per sq. in., the fiber stress under the required test pressure would be only 16,800 lb. per sq. in. On the ethylene tank, the fiber stress at the test pressure was 24,000 lb. per sq. in., or about 50 per cent greater than called for in the Code.) Having come to the conclusion, during the construction of this tank, however, that the 8000 lb. per sq. in. design fiber stress was too low for future construction, the pressure was further increased to 1000 lb., or the equivalent of three times the working pressure based on a design fiber stress of 9000 lb. per sq. in.

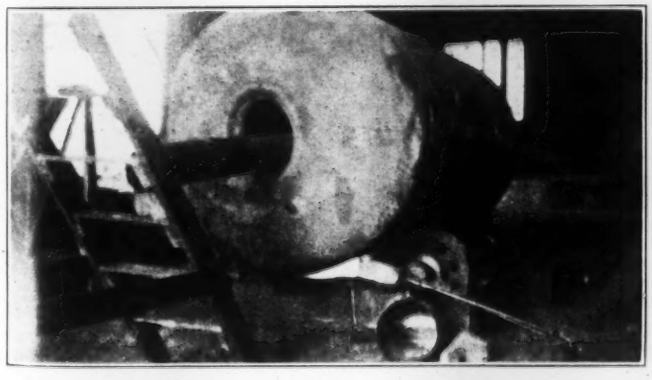

FIG. 14 WELDING INNER V BETWEEN FOURTH AND FIFTH COURSE. NOTE SYSTEM OF VENTILATION USED TO DRAW WELDING HEAT AWAY FROM OPERATOR

During these tests strain-gage measurements were taken at various points on the tank. These measurements, which have been analyzed in a detailed report prepared by Mr. T. W. Greene, indicated high stresses around the head knuckles and manhole, particularly about the latter. The tank therefore was again tested to 1000 lb. pressure to determine if there would be any increase in the permanent set at these points. The second test showed no evidence of distortion except in the metal about the manhole where there was a considerable increase in the permanent set.

The continuous yielding of the metal about the manhole at the 1000-lb. test pressure indicated a point of danger in the tank, and it was therefore decided to continue the test until no further permanent set occurred at the test pressure, or, if need be, to destruction. At 930 lb. pressure the tank failed through the manhole on the third application of the test pressure.[2] Figs. 15 and 16 illustrate the manner in which the manhead failure occurred.

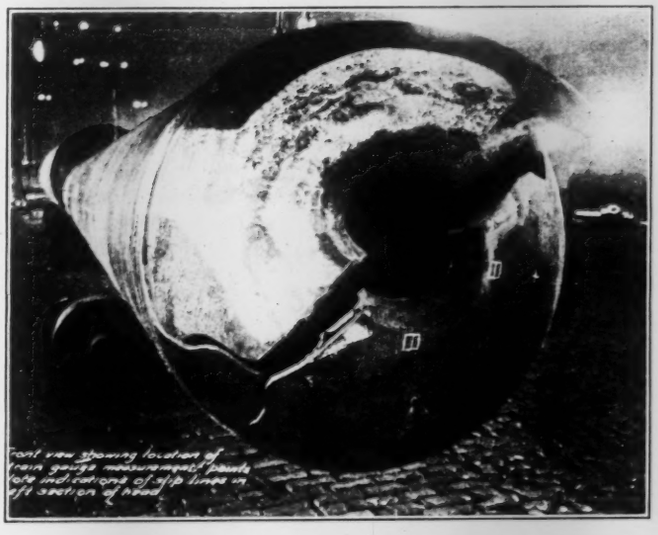

FIG. 15 FRONT VIEW OF HEAD FAILURE

FIG. 16 FRACTURE AT MANHOLE OPENING. NOTE SOLIDITY OF WELD METAL AND FUSION OF SADDLE PLATE TO MANHOLE

An examination of the head proved conclusively that the welds were in no way responsible for the failure as they were all intact except as severed cross-sectionally together with the saddle plate and manhead. On the other hand, this failure proved much in favor of the welded joint, the manhead girth weld and the longitudinal weld in the course adjacent to the manhead being in no way affected.

DESIGN OF NEW MANHOLE REINFORCING RING

In the repair of this tank it was only necessary to remove the defective head and reweld a new manhead, having in it a manhole

[2] This head failure is described by S. W. Miller in an article entitled, The Design of Dished Heads of Pressure Vessels, in MECHANICAL ENGINEERING, Aug., 1926, p. 845.

reinforcing ring of the requisite strength. The design of the new reinforcing ring, a sketch of which is shown in Fig. 17, was developed by our own engineering department. Because of the high test pressure to which the tank was to be subjected, a cover plate designed for a working pressure of 450 lb. per sq. in. was specified. The basis for this design and subsequent alterations in head design are covered in a paper written by Mr. A. B. Kinzel.

The new manhole reinforcing ring was produced from a steel slab, having the same chemical and physical properties specified for the shell plate. The slab was first cut by means of an oxyacetylene blowpipe to circular shape and then machined as required to produce the desired fillet and welding bevel. The elliptical manhole was cut out by means of an oxyacetylene blowpipe and the edges of the opening ground smooth.

The new manhead was constructed in accordance with our previous design, except that an 8-in. flange was specified to replace the metal removed from the first course in cutting off the defective head. After the head had been formed, however, it was necessary to remove a larger section from it than had been done on the previous head as the new manhole reinforcing ring was designed for butt

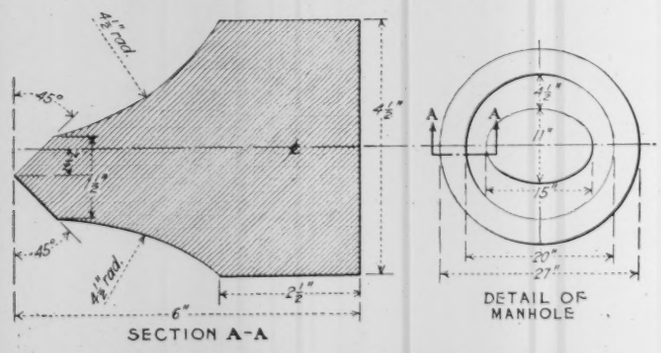

FIG. 17 SKETCH OF NEW MANHOLE REINFORCING RING

FIG. 18 WELDING REINFORCING RING TO MANHEAD. NOTE MEANS EMPLOYED TO PROTECT WELDER FROM HEAT

welding to the head rather than lap welding as had been employed in the previous construction.

WELDING NEW MANHOLE REINFORCING RING TO MANHEAD

The reinforcing ring was first set up and leveled at approximately the height required for attaching it to the manhead. The manhead was then lowered into position and after being blocked up to provide for a draft during preheating, was shimmed as required to bring the abutting edges of the reinforcing ring and manhead into alignment.

Four tack welds were next made at equidistant points on the seam, each two being made simultaneously at points 180 deg. apart. These tack welds were about four inches in length and without reinforcement.

After the tack welds had cooled, a firebrick preheating furnace was built about the entire head. This furnace was constructed in such a way as to provide the greatest amount of heat at the seam to be welded and in the heavy section of the manhole reinforcing ring. A natural draft was provided, entering through the openings between the blocks on which the head was set up and leaving through the elliptical opening in the reinforcing ring. Charcoal was used as the preheating medium, being distributed within the furnace through the elliptical opening. Asbestos paper was employed to cover the exposed section of the head.

Preheating was carried on until the manhole reinforcing ring and head in the vicinity of the weld had been brought up to a dull red. Welding was then started, using a long-handled blowpipe to keep the welder away from the heat. Fig. 18 illustrates in general the method employed in welding the first side of the double V.

After completing the weld from one side, all openings in the furnace were shut off and the head allowed to cool slowly and uniformly to room temperature. The excess metal was then chipped from the inner V as had been done on all other seams. Following this operation the head was set up for welding the inner V. It was then again preheated and welded. In order to eliminate any locked-up stresses, the head was completely annealed by placing it in a forge fire, bringing it up to an even heat and allowing it to cool slowly and uniformly.

FIG. 19 END OF TANK SHOWING NEW MANHOLE REINFORCING RING WELDED IN POSITION

FIG. 20 GENERAL VIEW OF TANK TAKEN DURING FINAL TEST

REWELDING MANHEAD TO SHELL

The new manhead was welded to the shell by the same method as employed on the last girth seam previous to the head failure. A forced draft was maintained against the head, however, when welding the inner V, to carry away the heat generated and maintain a low enough temperature to permit entrance to and emergence from the tank through the manhole. Figs. 19 and 20 show the new manhole reinforcing ring welded into the manhead and a general view of the completed tank.

RETEST OF TANK

The rewelding of the manhead girth seam having been completed, the tank was again subjected to the same tests previously indicated. Following the initial test in which the head adjusted itself somewhat to the theoretical elliptical shape, a reapplication of the pressure indicated that the stress in the head and manhole very closely approximated the design fiber stress. The tank was therefore accepted as safe.

A secondary test for gas tightness was next applied, the tank being subjected to an air pressure of 450 lb. per sq. in. Under this pressure all the welded seams were tested with soapy water, but not a single leak was discovered. The tank was therefore accepted and shipped to the customer.

SUMMARY

In the foregoing discussion the author has attempted to describe how the procedure involved in the construction of welded pressure vessels built under his company's supervision has been controlled; how, with respect to the last tank constructed, the welders were carefully checked before being allowed to weld on the tank and supervised thereafter to insure uniformity of performance throughout the work; how material of proper welding quality was specified and how this material was prepared for welding; how the welded joints, although designed on a fiber stress far exceeding that permitted by the A.S.M.E. Unfired Pressure Vessel Code withstood a test pressure which caused failure through a manhole saddle plate and head that had been based on a design previously considered safe for all types of construction and sanctioned by that Code; how when this point of weakness was discovered, a new manhole reinforcing ring was developed, and finally how under test the tank containing this reinforcing ring proved satisfactory.

No one will, the author believes, take issue with the statement that this tank is perfectly safe for operation under the designed working pressure. Welded-tank construction carried on under our observation since the completion of this tank has furthermore proved that the results obtained may readily be duplicated even when using a design fiber stress of 9000 lb. per sq. in. From their knowledge about the performance of small tanks, the author's company had convinced themselves that a much higher fiber stress could be used than had been recommended in current codes. When the problem of constructing large pressure vessels was presented, a gradual development was made, and by controlling the factors involved, it has been proved that size had no effect on the results obtained.

In the plant at which the tank under consideration was constructed, the welding of large pressure vessels has become a part of the regular production work. Procedure control methods have been thoroughly installed and this fabricator is now in a sound position to carry on welded-pressure-vessel work. Nor has the procedure adopted involved any regulations which would not be practical for any shop to adopt.

Many others interested in welding have come to the realization that uniformly successful results may be obtained in welded construction by the control of the factors involved, and as the development work carried on in this direction during the past few years is more generally appreciated, it is only logical to assume that engineering bodies and purchasers of pressure vessels will modify their ideas to permit a more liberal use of the inherent strength of welded joints.

Material Handling in the Port of New York

With Particular Reference to the Economic Aspects

BY JAMES A. JACKSON,[1] SCHENECTADY, N. Y.

IN COLLECTING data for this paper many conferences were held with representatives of large transportation companies to obtain their views, and the statements made by two men who hold positions of responsibility in two different companies are sufficiently interesting to be repeated. The author may not use their exact words, but in substance the first one said: "The Port of New York is still handling its freight as it did fifty years ago." The second one said: "The Port of New York is handling its freight as satisfactory and probably as economically as any port in the country."

There is perhaps some truth in both statements, and the whole truth probably falls somewhere between the two. However, to any one who has studied the situation carefully the fact cannot be overlooked that New York has made and is continuing to make pronounced progress in its methods of handling material and that the speed of this progress, which in the last analysis is going to be governed by economic conditions, is no doubt being made about as fast as these economic conditions will permit. In other words, to convert the Port of New York from what it was to what it ought to be must be by evolution and cannot be by revolution. Never in the history of our country has more attention been given to the development and introduction of more efficient methods in industry than at the present time, and material handling is one branch of our industry. Never before has money been spent any more freely for new facilities to speed up production and reduce costs than it is being spent today. The principal controlling factor of the rate at which money will be spent is the economic factor, namely, that it must be so spent as to earn a reasonable rate of return. This economic condition applies to the improvement of methods for handling freight in the Port of New York just as it applies to every other branch of industry. Now let us analyze some of the conditions which slow up the universal use of mechanical devices for handling material in the Port.

The Port is suffering from two conditions, one of which is beyond our control—its geography, and the other, which might have been controlled but was not, namely, its facilities, which to a large extent just grew instead of being planned.

Its geography, a wonderful asset with its fine harbor and great length of shoreline, makes it on the other hand largely a lighterage port, which necessitates extra handling of goods and adds the cost of operating the lighters—which some one must pay for, even though free lighterage is offered in many cases. Even with this handicap a tremendous improvement could be made if all facilities such as railroad tracks, steamship and railroad terminals, warehouses, car ferries, etc., could be relocated to the best advantage and all designed to fully utilize modern mechanical methods of handling material. To effect such a program will require years of time, millions of capital expenditure, and the overcoming of many other obstacles. This in general is the work being initiated by the Port of New York Authority, and its representative, Mr. Wilson, will no doubt agree that they have a long and complicated problem before them.

INTRODUCTION OF MECHANICAL-HANDLING DEVICES HITHERTO RETARDED BY DESIGN OF EXISTING STRUCTURES, PRESENT METHODS OF STEVEDORING, AND INSTALLATIONS NOT ECONOMICALLY JUSTIFIABLE

With this as a background we can turn to a closer study of the present use of mechanical devices for handling material. It is quite obvious that such a study must consider all conditions as they are and as they probably will be some years in the future, and not as we would like them to be. The use of mechanical devices is again subject to the economic law that they must pay a reasonable return on the invested capital to justify their use. It might be argued that in some cases machinery is justified even though it does not yield an adequate return on account of certain indirect benefits which may accrue from its use. It is often rather difficult, however, to make this argument convincing with privately owned operating companies, and where it is effective with publicly owned operated companies some one must stand for the direct operating loss, and that usually means that the public pays it in higher taxes.

One feature mitigating against the use of machinery is the design of existing structures. It is all very well to say, for example, that a pier should be equipped with a battery of cargo cranes such as is

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Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, March 1, 1927.

seen at Hamburg—and figures might be produced to show more economical handling by their use; but if the pier has foundations which will not stand the added weight and an area on which they cannot be successfully mounted, a complete new pier is necessary before the cranes may be used. The old pier may have many years of useful life under existing conditions of operation, and it would be exceedingly difficult in many cases to prove the economic justification of a new pier, even if physical conditions permitted the increased size, in order to get the advantage of crane operation. This is only an example, but many similar ones could be cited for other buildings and other types of machinery.

There is also the question of whether present established methods of stevedoring will permit the efficient use of machinery. These methods cannot be changed overnight, and a great deal of educational work faces those who attempt to introduce machinery which requires radical changes in methods. Fortunately, reports from industry as a whole and the views of labor leaders as expressed in public statements indicate that labor is becoming more receptive to improved mechanical methods, and as this feeling increases it will gradually spread to all branches of industry, including material handling, and make this problem easier to solve.

The introduction of mechanical devices has been further hampered by installations which have not proved their worth from an economic standpoint. The reasons why such installations have not been successful may have been due to any one or a combination of various causes, some of which are lack of accurate operating and cost data on which to base a reliable analysis of the problem, failure to appreciate the relation of existing stevedoring methods to operating methods required with the machinery to be used, geographical location of the installation in the port, failure of the tonnage handled to meet the anticipated amount, selection of a type of machinery not best suited to the peculiar requirements and operating conditions, etc.

No spirit of criticism is intended in any of the foregoing, it being merely an attempt to point out some of the difficulties confronting the Port, and to show by what follows that in spite of these handicaps the Port has progressed and is progressing in the use of mechanical handling devices.

METHODS NOW BEING USED IN HANDLING BULK FREIGHT

Starting with bulk freight, which best lends itself to the use of machinery, we find the Port using methods which are probably only surpassed by the Great Lakes ports—the most efficient in the world in this respect due, of course, to peculiar operation conditions, which cannot be duplicated in the Port of New York. Coal for ocean shipment is unloaded by nine car dumpers which can average a car of coal about every two minutes for each dumper. This means that each dumper if handling 70-ton-capacity cars could load a 5000-ton boat in about 5 hours, making reasonable allowance for shifting the boat and for other delays. Coal for the large power stations is handled by high-speed grab-bucket hoists handling from 250 to 300 tons per hour to heights of as much as 200 ft. with a power consumption of about 1 kw-hr. per ton. At this rate one hoist can unload a 5000-ton boat (the equivalent of 75 carloads) in about 24 hours. Smaller grab buckets and flight conveyors are handling the coal for local dealers, and, while not as efficient as the larger hoists, are certainly reducing labor costs to a minimum. There is no doubt an opportunity for increased efficiency by the consolidation of these small dealers, thus enabling them to combine their handling facilities and work them more effectively. Grain-handling facilities are quite adequately provided by five storage elevators with a capacity of seven million bushels and equipped for direct loading to vessels, twelve floating elevators for loading ocean vessels from barges, and one pneumatic floating elevator for transferring from ocean vessels to smaller boats. The charge for handling grain is one cent a bushel plus $1.50 per thousand, with an addition of $4 per thousand for trimming. One of the large storage elevators has a record of loading 221,000 bushels into a steamer in 16 hours, and could easily handle three or four such boats a week. Two railroads have just installed special machines for the direct transfer of grain from box cars to lighters alongside of the pier.

Bulk building materials such as sand and gravel, gypsum, etc., are handled by grab-bucket hoists of either the tower or mast-and-gaff types.

An extremely interesting development of the past few years has been in the handling of common building brick. Breakage and the necessity for stacking to economize in space required hand labor almost exclusively, but two methods recently developed practically abolish hand labor. One uses a container and cranes and is used where bricks are shipped in gondola cars, while the other uses no container but requires the bricks to be specially stacked so as to be handled by a special crane and tongs. This method is used for bricks coming in by lighters or barges. The first method used steel containers with doors at top and bottom each holding 3000 bricks. Twelve of these containers fill a special gondola car, and they are loaded at the brickyard while standing on the car. On arrival at New York the car is spotted under a gantry crane and an auto truck with a 3000-brick-capacity body runs alongside. The crane spots a container over the auto truck and the bottom doors are slowly opened by a second hook on the crane, thus depositing the brick in the truck gently and with little breakage. The container is then dropped back in the gondola. Twelve containers can be unloaded in about 45 minutes, whereas to unload a box car containing fewer bricks by the old hand method took from one to one and a half days. A single crane operating ten hours a day could unload in one day enough bricks to build 60 per cent of one wall of a building 300 ft. high and 100 ft. long, allowing for a normal number of window openings. This method of handling greatly reduces the cost, gives better service, and enables the railroad to handle the business with fewer cars and storage tracks.

For the lighter or barge method the green bricks are built in special stacks as they come from the molding machine, and these special stacks are maintained intact throughout the manufacturing process and until delivered to the building contractor. Each stack contains about 1500 bricks, and one or two stacks make a truck load, depending on the truck size. After manufacture is completed the crane with the special tongs loads the bricks on the barge by stacks, and at the New York end they are unloaded by similar cranes for delivery direct to trucks or to a storage pile where the stacks are still maintained intact. This permits piling 90 bricks high instead of 22, the economic limit by hand methods. Much ground area for storage is thus saved. Three hundred thousand bricks have been handled from barges to trucks in a day. One concern formerly required seven barges to handle their business with hand methods, whereas they now give better service with three. These methods represent a real advance in the art of mechanical handling of material.

Lumber is to a large extent being handled by machinery, usually cranes with special hooks, although there are possibilities of further improvement in handling this material.

MECHANICAL-HANDLING METHODS USED FOR PACKAGE FREIGHT

Now, turning to package freight, this falls into two general classes, viz., large packages weighing over 3000 lb., and small packages weighing under 3000 lb. While package freight does not lend itself to mechanical handling as readily as bulk freight, an immense tonnage is being handled very largely by mechanical means in the Port, and the use of machinery has been increasing rapidly within the last few years. As long as the Port remains to a large extent a lighterage port, floating cranes and derricks will be necessary, and a survey shows that there are 224 lighters equipped with power hoists of from 5 to 60 tons capacity. There are several larger than 60 tons for exceptionally heavy freight. While charges for the use of these heavy-capacity floating derricks are high and much time is consumed in towing them to and from the point where used, it is questionable as to whether many piers could justify the cost of a high-capacity pier crane to handle the tonnage of heavy freight passing over them, especially when the expense of foundations and redesign of pier are taken into consideration.

A number of piers have been especially built and equipped within the last few years for handling heavy packages up to about 20 tons such as boxed automobiles, knocked-down locomotives, boilers, etc. On one such pier the replacement of eight steam locomotive cranes with four heavy-capacity electric cranes reduced maintenance and labor costs by 55 per cent each, and the overall cost of operating the pier was cut in half. On another of these piers with two electric traveling cranes handling principally boxed

automobiles, it was reported that the cranes avoided all shifting of barges with consequent delay and expense of tugs, and that the capacity of the pier had been increased approximately three times over the old method of using steam-operated locomotive cranes. There are at the present time close to fifty electrically operated cargo jib cranes of between $2^1/_2$ and 20 tons capacity in the harbor, the majority of which have been installed since the war. In addition to this the railroads are equipped with pillar or gantry cranes for handling heavy loads between cars and trucks. Thus material progress has been made in the use of heavy package-handling machinery and economies are being effected.

Turning now to light packages, ships winches, supplemented at times by dock winches, are still in general use for loading and unloading ships. While there may be disadvantages to this method, the change to other methods will be slow for the reasons pointed out in the first part of the paper. However, improvements have been made in handling methods on the piers by the use of electric trucks and tractors with trailers, conveyors, piling machines, and power ramps. The economical use of this type of machinery is, however, handicapped by the size of many piers, while on others the short average movement does not justify their use; thus their universal use cannot be expected for many years. Several of the railroads have made quite extensive use of electric trucks and trailers on their pier stations for handling car ferries, with very efficient results if statements as quoted below are typical. One superintendent writes:

> This freight-handling equipment has made a reduction in handling cost and almost eliminated dock shortages and misloading. One of its great advantages is that freight is practically cleaned up at all times. This makes it possible to get floats away from the piers a few minutes after closing time for the receipt of freight. One of the advantages to shippers is the fact that there is practically no delay in releasing shippers' trucks at bulkheads. It is noticeable that the congestion which used to exist in front of railroad freight piers no longer exists when electric trucks are used, and in this way the truck operation has perhaps benefited the shipping public even more than the railroad.

Another superintendent wrote as follows regarding the use of tractors and trailers and electric lift trucks with skids.

> The principal advantage of the mechanical equipment applies to the handling of forwarded business in that it avoids docking and reloading such freight, with the result that less man-hours are necessary and the bulkhead is kept open for the continuous receipt of freight, thus reducing truck detention. The equipment now in use has greatly contributed to efficient operation, making possible the handling of greater volume of business through the same pier facilities at reduced labor cost. At our largest pier, with very slight increase in facilities, it was possible to increase tonnage handled per annum approximately 50 per cent. Without the mechanical equipment this increased volume of business could not have been handled and our labor cost would have been approximately five cents per ton greater than present cost.

He further states that this estimate on labor cost is very conservative. In another case it was reported that the use of electric trucks carrying small cranes had cut in half the labor required on the pier when handling certain classes of freight. No figures were available on the number of piers, railroad terminals, and warehouses using power trucks and tractors, but their use has spread rapidly within the past six or eight years, and has probably been as fast as economic conditions would permit.

Power ramps have been put on a number of piers unloading from lighters, barges, and side-port vessels where tide and draft conditions make the grades too steep for one man to handle a hand truck and where the operating conditions on the pier are such that electric trucks cannot be efficiently used. On one such pier which is working up to capacity every day with night work part of the time, these ramps reduced the direct labor 33 per cent and the time of climbing the ramps was cut in half. The same type of power ramp is used on some piers between the first and second stories to replace elevators, but no statistics are available to show the economies of one over the other.

Many warehouses are now using electric trucks with elevator service between floors, but here again there was not time to collect statistics on the savings effected thereby, although their increasing use indicates a saving. This method of operation is replacing the whip hoists for hoisting from ground to upper floors, which method requires trucking from ship or car to hoist, hoisting to upper floor, and trucking to destination. The electric-truck and elevator method maintains the load intact on the truck from ship or car to destination.

Various types of containers are coming into more general use not only on railroads but in department stores for the delivery of goods and the transfer of goods between warehouses and retail stores. The size of these containers requires power equipment, usually small electric hoists, to handle them.

The detachable-body auto truck with increasing capacities is coming into more general use, thus permitting the expensive power plant and chassis with its operator to be kept more continually at work.

Conveyors of the power and gravity type are finding more general application for both bulk and package freight in manufacturing plants where the flow is sufficiently continuous to justify their installation and use.

Pilers and stackers are economizing in expensive floor space by permitting higher piling with less labor.

Small power hoists are being installed in large numbers, whereas few were used ten years ago.

It can safely be said that, as a general thing, material-handling machinery tends to create dispatch instead of delay, to bring order out of chaos, and to reduce the required area per ton handled.

The entire material-handling branch of industry is being put on a firmer foundation by the accumulation of statistics and experience, and a committee of the A.S.M.E. has worked out a formula for calculating the economies resulting from the use of power-driven material-handling machinery.

To sum up, the Port of New York has progressed and will continue to progress in this field in spite of the conditions referred to previously in this paper, because competition and labor shortage will compel such progress. The rate of this progress will be governed very largely by economic conditions and laws, but it will be accelerated to some extent by the acquisition of more complete knowledge on the application and use of mechanical devices.

Welded Steel for Machine Bases

THE use of welded steel in place of castings was discussed by J. F. Lincoln, vice-president of the Lincoln Electric Co., Cleveland, Ohio, in his address, Arc Welding as Applied to Manufacturing, at a joint meeting of Engineers' Club of Philadelphia and the Philadelphia Section of the American Welding Society on February 21. The physical characteristics of steel as compared with cast iron were outlined to show the greater economy of steel shapes joined by arc welding.

The use of structural steel for bases of machines was discussed and some of the steps in redesigning such machine parts for arc welding were outlined, it being shown that it is less difficult to design a machine base of arc-welded steel. The designer in welded steel works directly for the ultimate result, it being unnecessary for him to allow for casting shrinkage, draft on patterns, cores, fillets, etc.

Application of welded steel in the manufacture of lathe beds was of interest. Since such a bed is called upon to withstand a bending stress, the steel section best suited for the purpose was said to be the I-beam. Instead of the heavy cast-iron base, two I-beams would be joined solidly together by arc-welded cross-braces. The legs would be made either of I-beams, standard channels, or angles. Hardened steel ways screwed to the tops of the I-beams would replace the cast-iron ways, the steel ways being readily renewable when worn. The welded-steel lathe would be stronger, lighter, and cheaper, said Mr. Lincoln, although obviously it would not look the same.

Advantages claimed for the substitution of welded steel for cast iron included reduction in cost of development work of a new design; elimination of pattern expense; elimination of obsolete parts; reduction in amount and cost of necessary machining, and reduction in raw-material inventory and total material cost.

Mr. Lincoln stated that his company has largely eliminated the use of castings in its products, and that the inventory of steel is less than 11 per cent of the former casting inventory. This saving in inventory, he pointed out, would be greater where castings are used on a large scale in the product.—From report of meeting in *The Iron Age*, March 3, 1927, p. 646.

Tolerance and Allowance Charts for Metal Fits

By T. F. GITHENS,[1] CLEVELAND, OHIO

THE A.S.M.E. Sectional Committee on Plain Limit Gages for General Engineering Work has produced an excellent set of tables in its report entitled "Tolerances, Allowances, and Gages for Metal Fits." This is the Engineering and Industrial Standard B4a–1925.

The author has prepared the accompanying series of charts graphically showing the information tabulated in the above report, for the convenience of those who find it preferable to use charts instead of tables of figures.

As an example showing the use of the charts, suppose that the allowance and tolerances for a loose fit $2^1/_8$ in. in diameter are required. Locating the $2^1/_8$-in. diameter on Fig. 1, we read that the hole has a tolerance of +0.003 and —0.000; that the allowance is —0.004, and the tolerance on the shaft is —0.004 and —0.007 from standard. Therefore the hole dimensions are $2.125\ ^{+0.003}_{-0.000}$ and the shaft dimensions are $2.121\ ^{+0.000}_{-0.003}$. The loosest fit is between the 2.128 hole and 2.118 shaft (0.010 difference). The tightest fit is between the 2.125 hole and the 2.121 shaft (0.004 difference). The latter is the fit "aimed" at, the former is "tolerated." (NOTE.—Where the chart steps up, as at $2^3/_4$ in., for example, the lower value of the tolerance is the one taken. In other words, from $2^3/_8$ in. to $2^3/_4$ in., inclusive, the hole tolerance is +0.003 and —0.000. Above $2^3/_4$ in., the tolerance increases to +0.004 and —0.000.)

As another example, take the tight fit of $^3/_4$ in. Locating the $^3/_4$-in. diameter on Fig. 6, we read that the hole has a tolerance of +0.0005 and —0.0000, that the shaft has a tolerance of +0.0007 and +0.0002, and that the selected average interference of metal is +0.0002. For the correct conditions, then, a shaft of 0.7507 in. must be fitted into a hole of 0.7505 in., and a shaft of 0.7502 in. must be fitted into a hole of 0.7500 in. In other words, the large shafts must be selected to fit into the large holes, small shafts into small holes, and medium shafts into medium holes (i.e., shaft 0.7503 into hole 0.7501, shaft 0.7504 into hole 0.7502, shaft 0.7505 into hole 0.7503, shaft 0.7506 into hole 0.7504.)

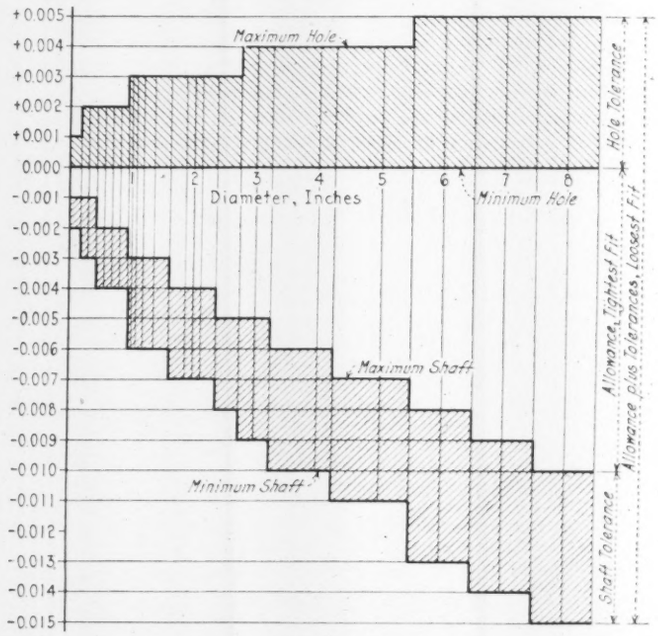

FIG 1 LOOSE FIT (CLASS 1)—LARGE ALLOWANCE, INTERCHANGEABLE

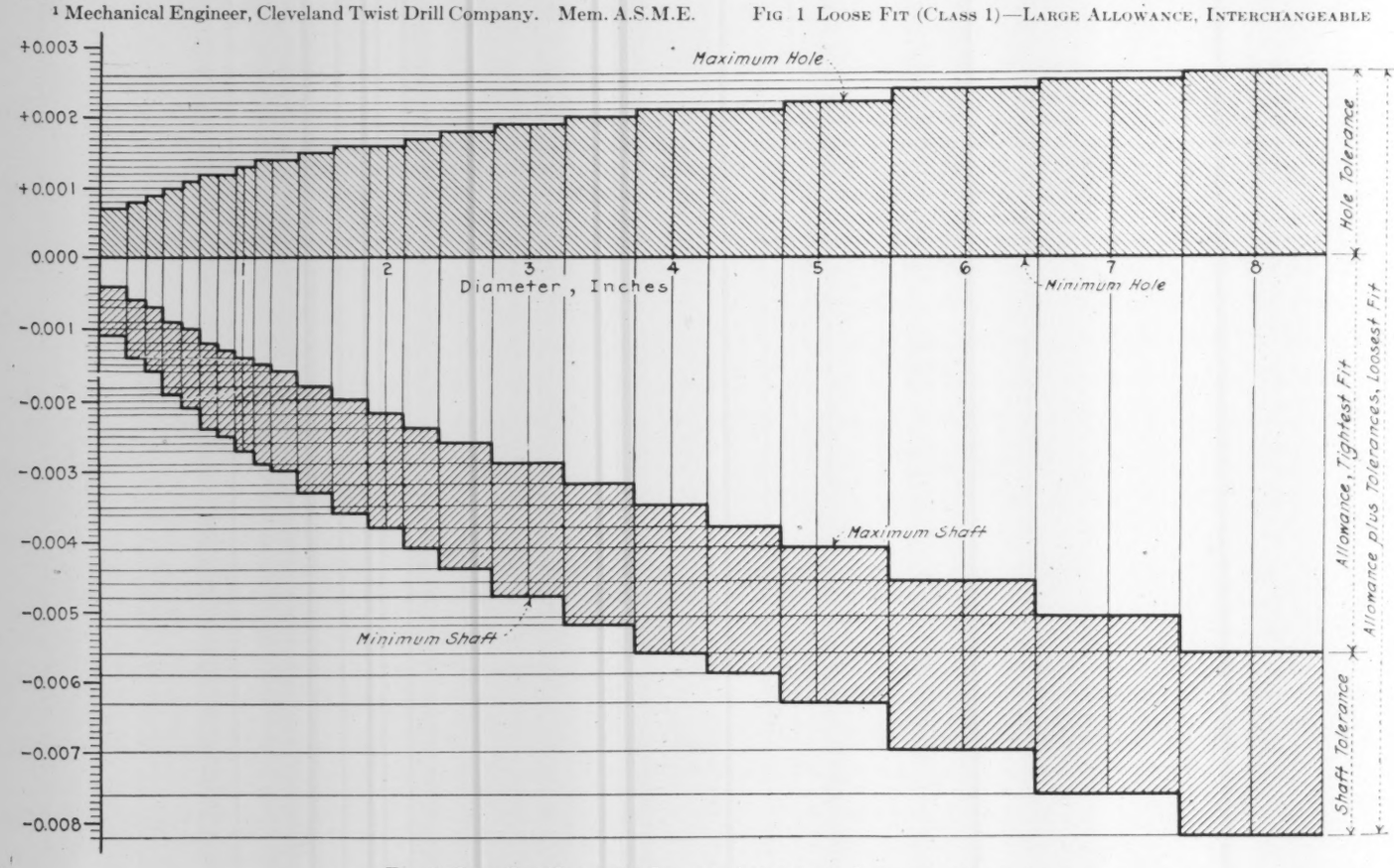

FIG. 2 FREE FIT (CLASS 2)—LIBERAL ALLOWANCE, INTERCHANGEABLE

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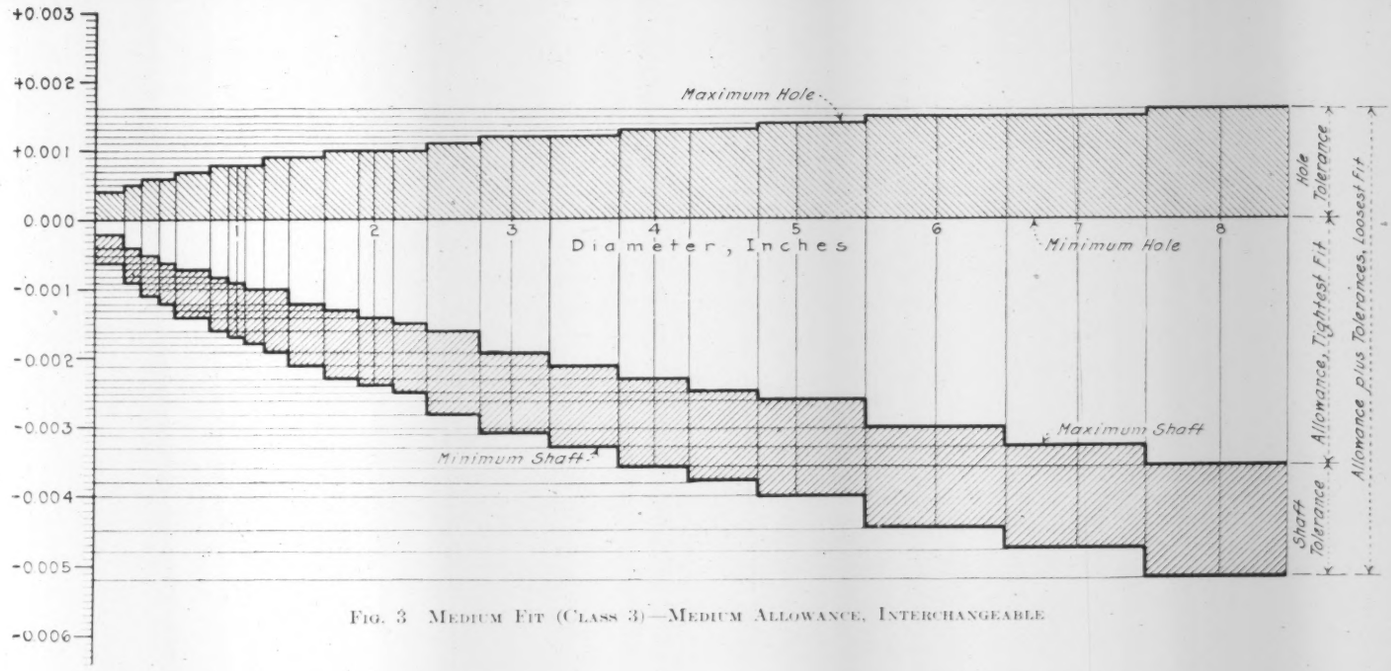
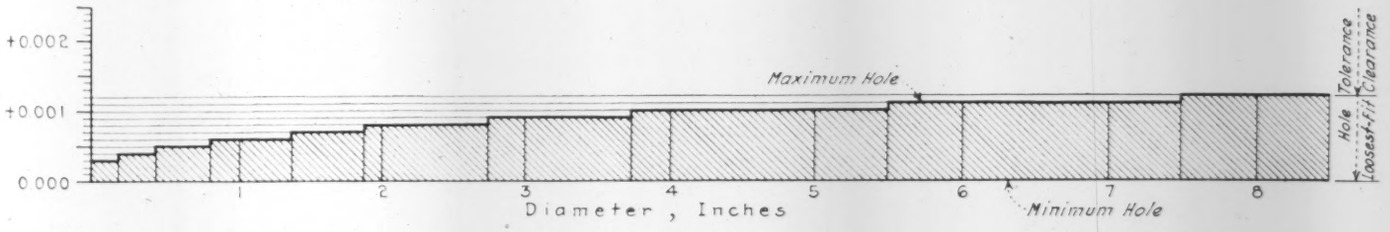


FIG. 3 MEDIUM FIT (CLASS 3)—MEDIUM ALLOWANCE, INTERCHANGEABLE



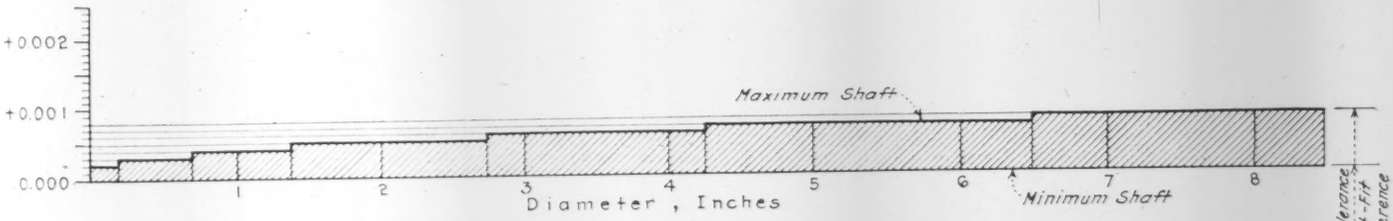
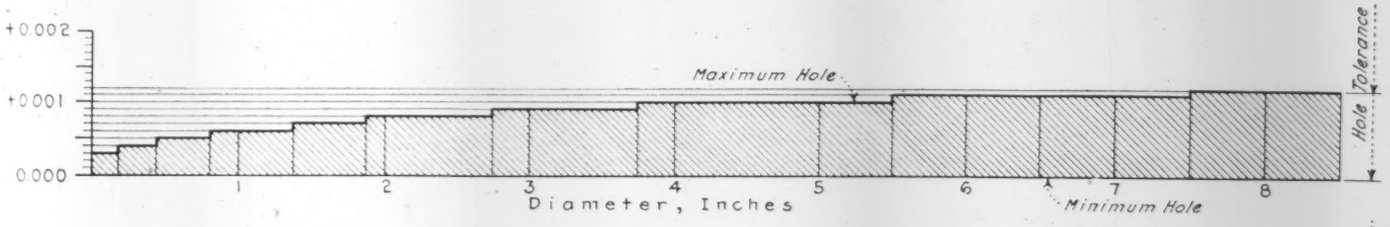


FIG. 5 WRINGING FIT (CLASS 5)—ZERO TO NEGATIVE ALLOWANCE, SELECTIVE ASSEMBLY



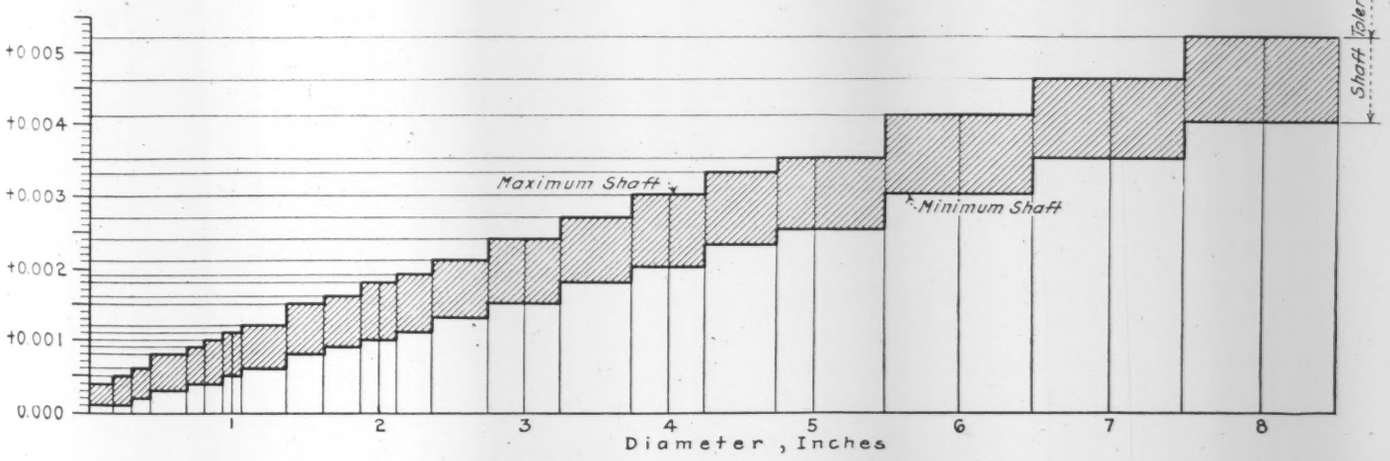


FIG. 7 MEDIUM FORCE FIT (CLASS 7)—NEGATIVE ALLOWANCE, SELECTIVE ASSEMBLY

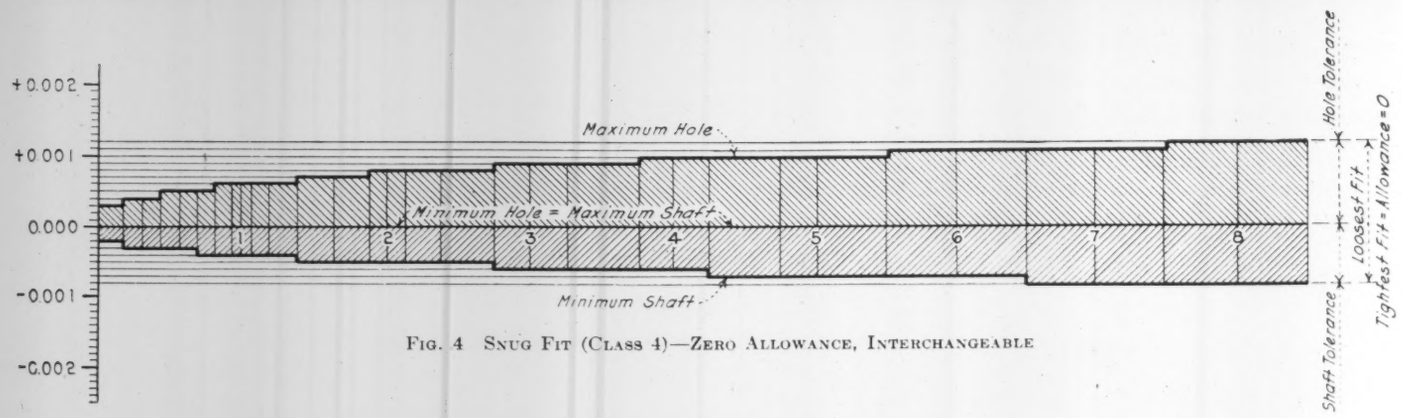


FIG. 4 SNUG FIT (CLASS 4)—ZERO ALLOWANCE, INTERCHANGEABLE

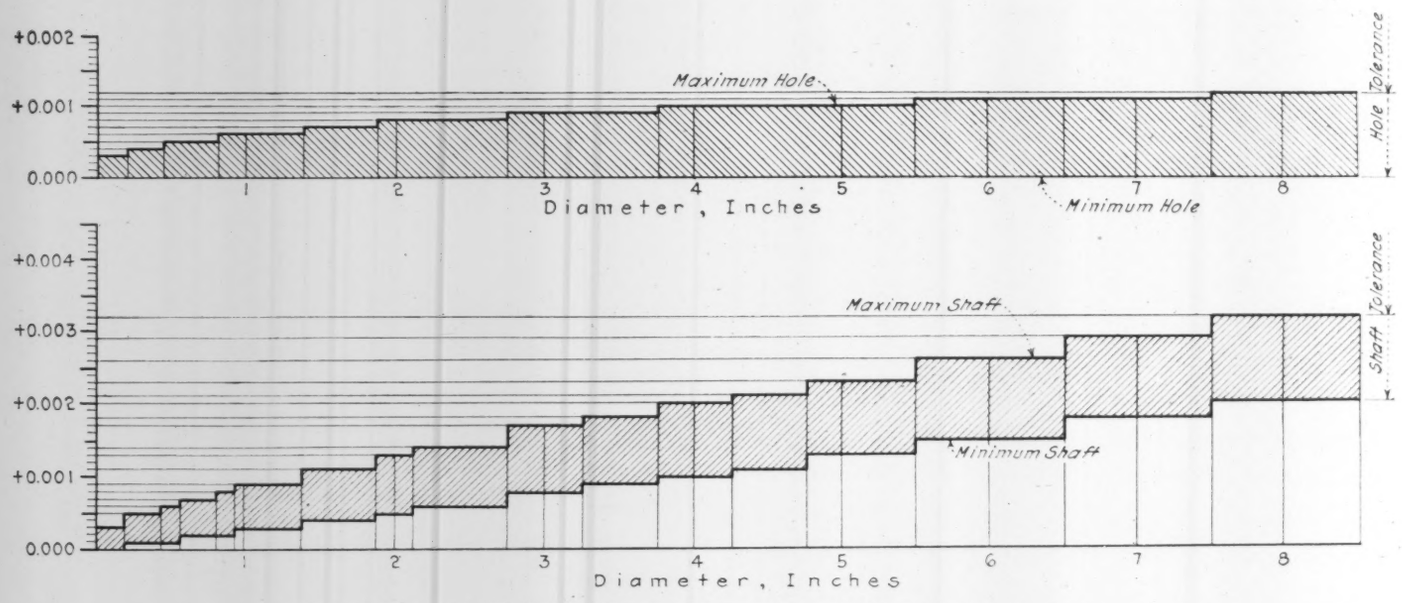


FIG. 6 TIGHT FIT (CLASS 6)—SLIGHT NEGATIVE ALLOWANCE, SELECTIVE ASSEMBLY

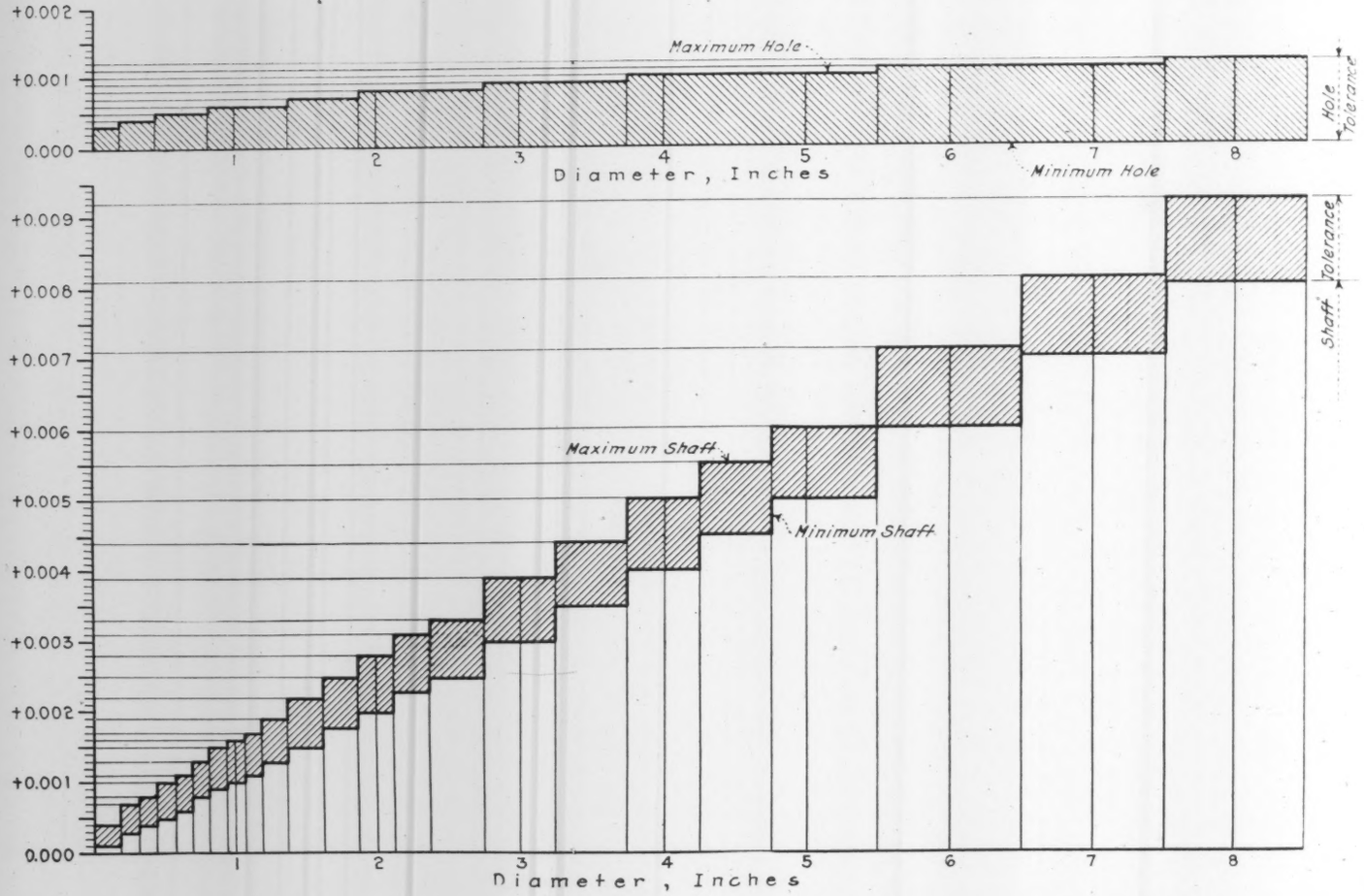


FIG. 8 HEAVY FORCE AND SHRINK FIT (CLASS 8)—CONSIDERABLE NEGATIVE ALLOWANCE, SELECTIVE ASSEMBLY

Surface Condensers in Steam Power Plants

A Study Showing How the Most Economical Condenser Installation for a Given Power Plant Can Be Determined—Based on an Average Heat Transfer Actually Obtained in Condensers of Different Makes Under Normal Operating Conditions

By J. A. POWELL[1] and H. J. VETLESEN,[2] READING, PA.

THE type and size of condensers to be installed in a power plant is a subject which has recently been much discussed by engineers connected with the manufacture and sale of condensing plants. The ratio of square feet of condenser surface to kilowatts output of the turbine it serves has been taken as a measure for the relative size of a condenser, and this ratio has been gradually reduced during the last few years. The ratio now recommended by the different manufacturers varies widely, however, according to the condenser design of the individual manufacturer. The discussions regarding the best condenser installation which have appeared in different technical papers recently have so far been merely technical. For the power-plant engineer, however, the problem of selecting the most economical condenser for a particular unit is not merely a technical one but essentially of an economic nature, and has to be studied accordingly.

The purpose of the present paper is to show how such a study is made, by means of which the most economical condenser installation for a given power plant can be determined. As it is not the aim to discuss the advantages or disadvantages of the various makes of condensers, the study is based upon an average heat transfer which actually has been obtained in condensers of different makes under normal operating conditions.

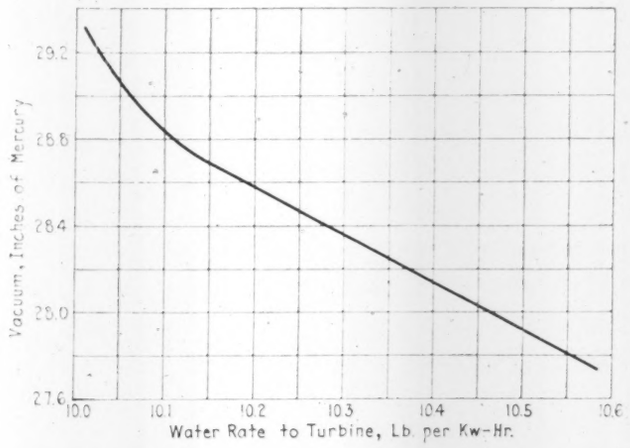


FIG. 1 WATER RATE WITH BLEEDING AT VARIOUS VACUUMS
(Two-stage feed heating to 212 deg. fahr.; 26,000 kw. load.)

As a basis for the study the authors have taken a normal load of 26,000 kw. on a 30,000-kw. turbo-generator, bled at two stages for preheating of the feedwater to 212 deg. fahr., the turbine giving a yearly output of 100,000,000-kw-hr. The variation in steam supplied to the turbine at 26,000 kw. load with change in vacuum was found and plotted as a water-rate curve.

The calculation of the vacuum which can be obtained with a condenser is based on the heat transfer obtained with tubes in normal operating condition, and not on the heat transfer obtained with absolutely clean tubes. This heat transfer, expressed in B.t.u. per square foot per degree fahrenheit per hour, varies with the inlet temperature of the circulating water, with the velocity of the water in the tubes, and with the tube arrangement and design of the condenser. Actual performance data on heat transfer for different makes of condensers with the tubes in normal operating condition were gathered, and curves (Fig. 2) were worked out giving the average values found at different inlet water temperatures. The average inlet water temperature in this study was assumed to be 50 deg. fahr., and the corresponding heat transfer, at different water velocities in the tubes, was found from Fig. 2.

This heat transfer gives the basis for the calculation of the vacuum obtained with any condenser, with tubes of a certain gage and length. If the dimensions of the tubes to be used are known, the water quantity and the friction head through a single- or two-pass condenser for any water velocity can be calculated.

The method by which the vacuum, the steam consumption, and the total yearly operating costs are calculated is explained later in an appendix.

The total yearly operating costs thus found do not represent absolute values but are comparative figures, as only the differences in operating costs for tube maintenance, horsepower costs, and fixed charges are tabulated. As comparative figures the costs give, however, the information wanted regarding the most economical size and type of condenser to be installed. The costs thus obtained were plotted against water velocity, as shown for the single-pass condenser in Fig. 6, and for the two-pass condenser in Fig. 7.

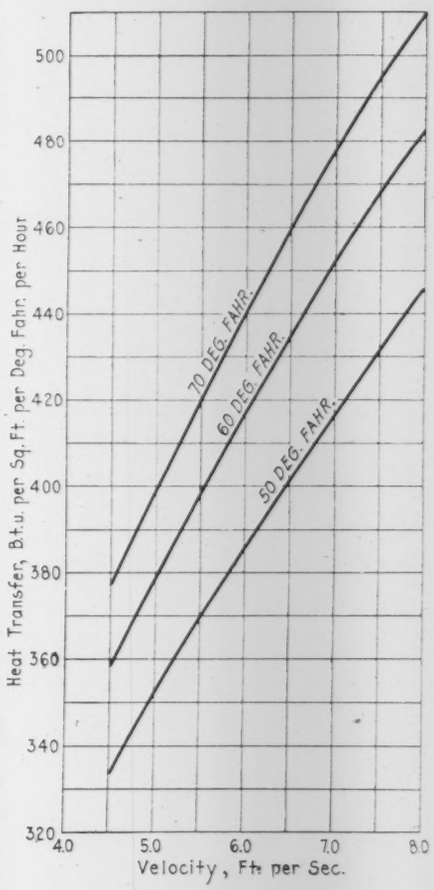


FIG. 2 HEAT TRANSFER AT DIFFERENT VELOCITIES AND TEMPERATURES

The curves thus plotted give the comparative yearly operating costs and show that the single-pass type of surface condenser, although requiring more circulating water, is more economical than the two-pass type. If an ample supply of circulating water is available, a single-pass condenser should be installed.

The curves further indicate that, within the range of the condensers considered in this study, the condenser with the smaller surface is a more economical installation than the one with a larger surface. The economical advantage of installing a small condenser is more marked with a single-pass than with a two-pass condenser. The curves for the two-pass condensers show, in fact, that with low water velocities the 25,000-sq. ft. condenser is more economical than the 20,000-sq. ft. condenser. For the single-pass condenser, the 20,000-sq. ft. shows a marked economical advantage over the 25,000-sq. ft. condenser. In order to determine whether a still smaller surface than 20,000 sq. ft. would be advantageous, the yearly operating costs with an 18,000-sq. ft. condenser were calculated and the corresponding curve added in Fig. 6. This curve indicates only a slight advantage with an 18,000-sq. ft. condenser

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Presented at a meeting of the Philadelphia Section of the A.S.M.E., April 26, 1927.

when the water velocity is over 6.25 ft. per sec., and a considerable loss at lower water velocities, showing that, for the conditions considered, it would not be advisable to install a single-pass condenser with less than 20,000 sq. ft. of surface.

The ratio of condenser surface in square feet to normal turbine output in kilowatts is 20,000 to 26,000, or 0.77. This ratio, for the most economical condenser installation, is astonishingly low, especially when it is considered that the heat transfer assumed is an average value actually obtained, and may be considered conservatively low compared with values guaranteed with modern condensers. An investigation regarding condenser installations in modern power plants shows that, among forty of the most prominent power stations completed within the last two years, only two have a ratio of condenser surface to kilowatt output under 1.0. This ratio for

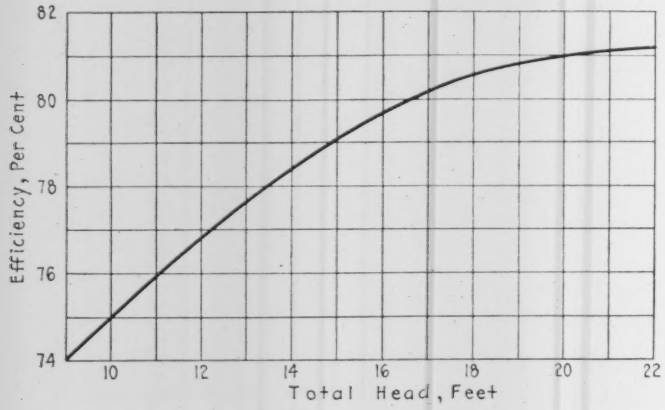


FIG. 3 EFFICIENCY OF CIRCULATING-WATER PUMP

the different stations varies considerably, one being as high as 2.75, and the average for all stations being 1.396.

This study would indicate that the condensers generally installed have an excessive amount of surface and that better economical results will be obtained when well-designed condensers with smaller surfaces are installed.

As the study made refers to special conditions, although these may be regarded as fairly normal, it may be questioned whether the result obtained applies to condenser installations in general. In order to determine this, the influence of different conditions on the result will be discussed.

INFLUENCE OF DIFFERENT CONDITIONS ON RESULT OF STUDY

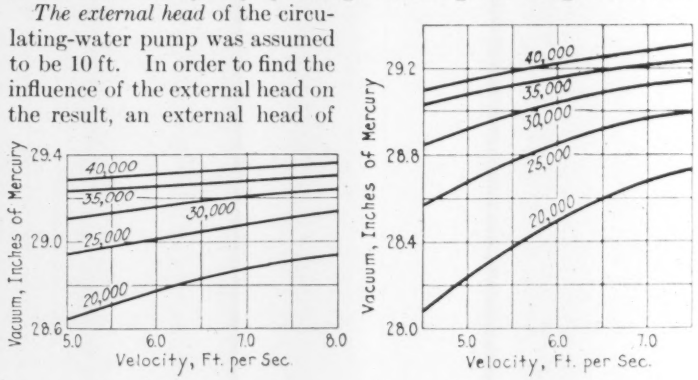
The temperature of the circulating water is one of the main factors to be considered when a condenser installation is decided upon. The average inlet water temperature considered in the above study was 50 deg. fahr., which may be regarded as somewhat low. Vacuums obtained with 60 deg. fahr. and 70 deg. fahr. mean inlet water temperatures were therefore calculated and the corresponding yearly operating costs found and plotted as curves. In order to get a clear picture of the conditions, only the curves for the smaller condensers were plotted in Figs. 8 and 9, which figures show the influence of the inlet water temperature on both types of condensers. As the single-pass condenser is the more economical installation, the influence of the warmer circulating water on this type of condenser is of main interest. Fig. 8 shows that, with a water temperature of 60 deg. fahr., a 20,000-sq. ft. condenser is still the most economical for water velocities above about 5.75 ft. per sec., and at 70 deg. fahr. water temperature the 20,000-sq. ft. condenser remains more economical than the 25,000-sq. ft. condenser for water velocities above about 6.25 ft. per sec.

The load factor on the unit may have an influence on the result. The yearly output was assumed to be 100,000,000 kw-hr. In order to find the effect on the final result with change in load factor, the yearly operating costs were also calculated for a yearly output of 150,000,000 kw-hr. and 50,000,000 kw-hr., and plotted as curves in Figs. 12 and 14 for the single-pass, and in Figs. 13 and 15 for the two-pass condenser. It will be seen that for the single-pass type the 20,000-sq. ft. condenser shows an advantage over the next larger condenser at all load factors considered, the advantage increasing with lower load factors. For a two-pass type, a 25,000-sq. ft. condenser would be more economical to install than a 20,000-sq. ft. one, at the highest load factor considered. A difference in coal price will have the same influence on the result as a difference in load factor, only to a smaller degree, as the price of coal will not vary to such a great extent.

Heating of the feedwater by means of steam bled from the turbine up to 212 deg. fahr. has been assumed, which can be attained with steam at atmospheric pressure and without any part of the heating system under pressure. Some of the recent installations, however, use heaters under pressure, whereby considerably higher feedwater temperatures are attained, the quantity of steam exhausted to the condenser is reduced, and the installation of smaller condensers is justified. If the turbine is working straight condensing (Fig. 18), the single-pass 20,000-sq. ft. condenser is the most economical condenser for water velocities above about 6 ft. per sec. (Fig. 20). If a two-pass condenser has to be installed, a 25,000-sq. ft. one is more economical (Fig. 19).

The curve for variation in steam consumption with variation in vacuum at normal load given in Fig. 1 will not change considerably in character for other turbines and steam conditions, although the actual values may be different. As the variation in steam consumption is used for the calculation and not the actual figures, the curve may be regarded as characteristic for turbines running at normal load with bleeding for feed heating to 212 deg. fahr. The upward bend in the water-rate curve is due to the fact that the dimensions of the exhaust end of the turbine do not allow the highest vacuums to be fully utilized at 26,000 kw. load. Assuming that a turbine with a large exhaust end were used, whereby higher vacuums could be fully utilized, a straight-line water rate would be obtained. The effects on the yearly operating costs are given in Figs. 16 and 17.

The external head of the circulating-water pump was assumed to be 10 ft. In order to find the influence of the external head on the result, an external head of



FIGS. 4 AND 5 VACUUM AT VARIOUS WATER VELOCITIES
(Based on 26,000 kw. load; 233,000 lb. steam condensed per hour; 50 deg. fahr. inlet water temperature; $^{7}/_{8}$-in. O.D. tubes.)

20 ft. instead of 10 ft. was assumed and the pump efficiency given in Fig. 3 assumed correct for a pump built for 10 ft. higher total head. The effect on the yearly operating costs is given in Fig. 10 for the single-pass condenser and in Fig. 11 for the two-pass condenser, and these show that with higher heads the economical advantage of installing a smaller condenser will not be altered, the main effect being that the costs at higher water velocities are comparatively higher.

The water velocity in the tubes may have some influence on the cost for cleaning the tubes, as with higher water velocities the scoring effect of the water in the tubes will increase and less frequent cleaning may be necessary. To express this effect as a saving in dollars and cents is difficult, and no endeavor has been made to include it in the yearly operating costs. It is, however, advisable to have this possible saving in mind when the water velocity is being determined.

CONCLUSION

The foregoing study shows that with sufficient circulating water the most economical condenser installation for a unit is a single-pass condenser for which the ratio of square feet of surface to normal kilowatt output of the turbine it serves is not higher than about 0.77.

With higher water temperatures the installation of the smaller condenser is justified only at higher water velocities. At 60 deg. fahr. water temperature the installation of a surface condenser with a ratio of surface to kilowatt output of 0.77 is justified for

Fig. 6 Single-Pass Condenser, 50 deg. Fahr. Inlet Water Temperatures, 100,000,000 Kw-Hr. Yearly Output.

Fig. 7 Two-Pass Condenser, 50 Deg. Fahr. Inlet Water-Temperature, 100,000,000 Kw-Hr. Yearly Output.

Fig. 8 Single-Pass Condenser, Various Inlet Water Temperatures, 100,000,000 Kw-Hr. Yearly Output.

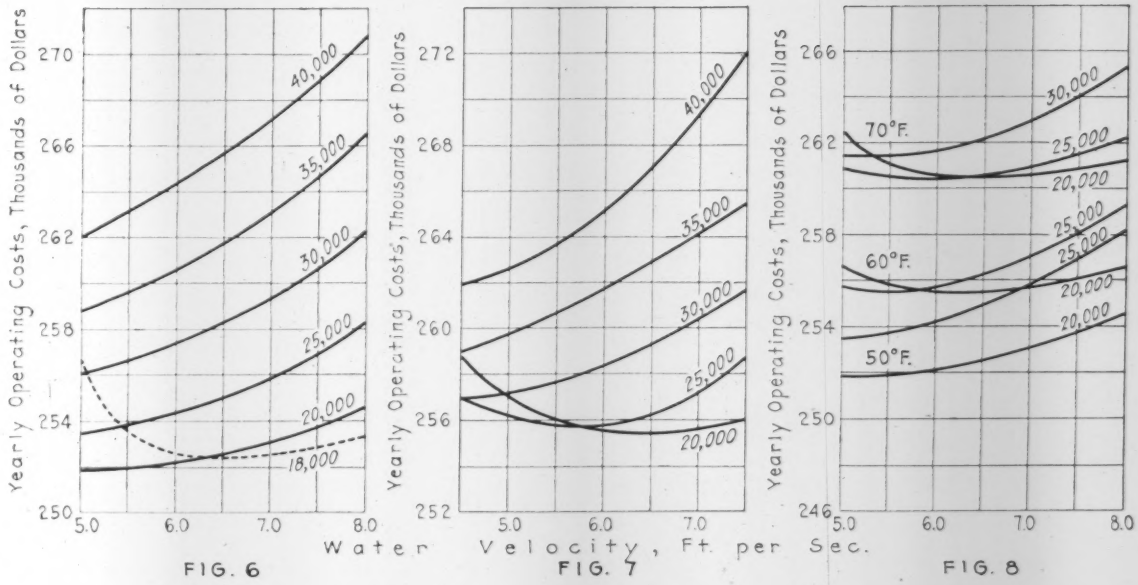


FIG. 6 FIG. 7 FIG. 8

Fig. 9 Two-Pass Condenser, Various Inlet Water Temperatures, 100,000,000 Kw-Hr. Yearly Output.

Fig. 10 Single-Pass Condenser, 50 Deg. Fahr. Inlet Water Temperature, 100,000,000 Kw-Hr. Yearly Output. (Solid lines: 20 ft. external head; broken lines, 10 ft. external head.)

Fig. 11 Two-Pass Condenser, 50 Deg. Fahr. Inlet Water Temperature, 100,000,000 Kw-Hr. Yearly Output. (Solid lines: 20 ft. external head; broken lines, 10 ft. external head.)

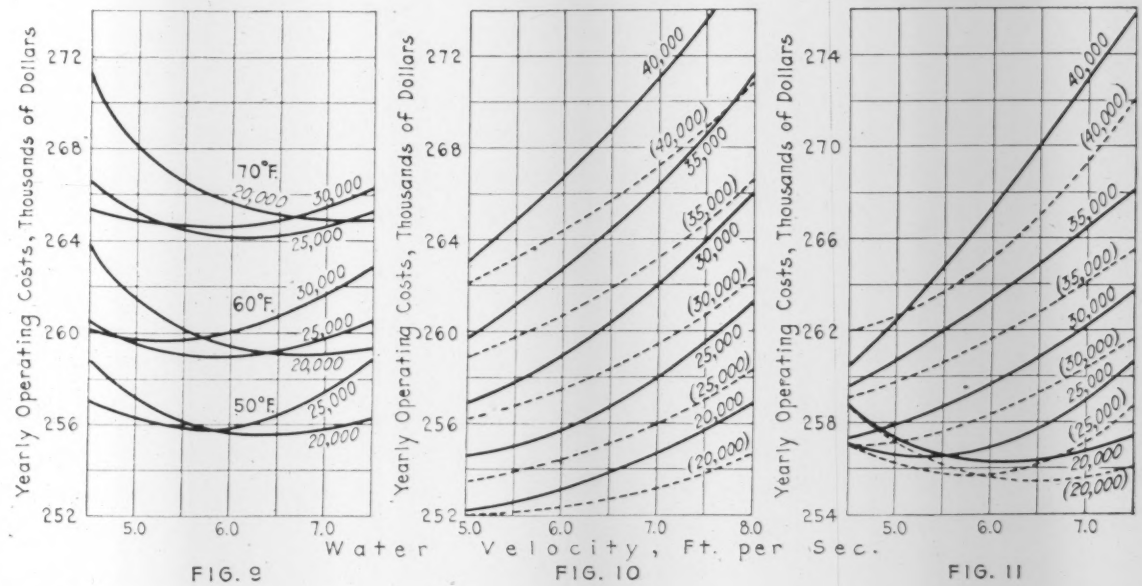


FIG. 9 FIG. 10 FIG. 11

Fig. 12 Single-Pass Condenser, 50 Deg. Fahr. Inlet Water Temperature, 150,000,000 Kw-Hr. Yearly Output.

Fig. 13 Two-Pass Condenser, 50 Deg. Fahr. Inlet Water Temperature, 150,000,000 Kw-Hr. Yearly Output.

Fig. 14 Single-Pass Condenser, 50 Deg. Fahr. Inlet Water Temperature, 50,000,000 Kw-Hr. Yearly Output.

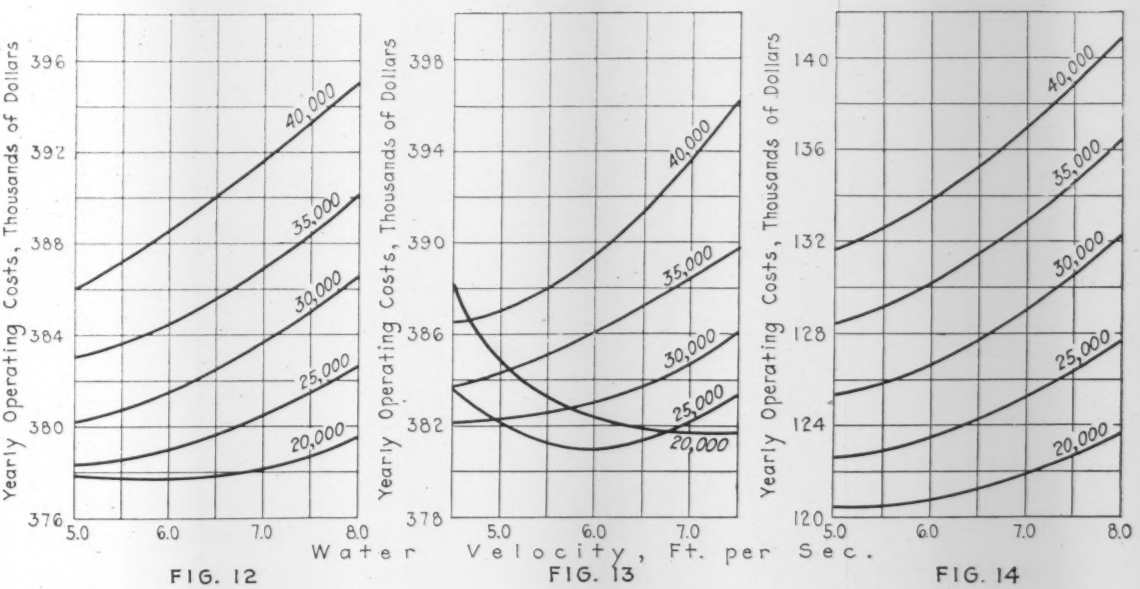


FIG. 12 FIG. 13 FIG. 14

FIGS. 6–14 YEARLY OPERATING COSTS OF CONDENSERS AT VARIOUS WATER VELOCITIES
(Based on 26,000 kw. load; 233,000 lb. steam condensed per hour; 7/8-in. O.D. tubes.)

water velocities through the tubes above about 5.75 ft. per sec., and at 70 deg. fahr. water temperature for water velocities above about 6.25 ft. per sec. The most economical surface-condenser installation thus found is considerably smaller than that actually installed in modern power plants. The study was based on heat-transfer figures actually obtained under normal operating conditions; these figures are considerably lower than guarantees now given by most manufacturers, and therefore must be considered as fairly conservative.

Appendix

THE method of calculating the vacuum is shown in Table 1. The steam quantity exhausting to the condenser was found to be about 233,000 lb. per hr., and regarded as constant for the calculation of the vacuum obtainable with condensers of different surface areas and with different water velocities in the tubes. The error of not making a correction for the assumed quantity of steam exhausted to the condenser with the change in vacuum is only slight, the maximum error on the final water rate found being 0.45 per cent. With a constant steam quantity of 233,000 lb. per hr. to the condenser, the table is worked out for a water velocity in the tubes of 5 ft. per sec., with a corresponding friction of 4.2 ft. through the single-pass condenser. The temperature rise of the circulating water Δt is easily found: $\Delta t = S \times H/W$, where S = steam to condenser, lb. per hr., H = heat content of the exhaust steam, B.t.u. per lb. of steam, and W = weight of water, lb. per hr.

The mean water temperature with an inlet water temperature of $t = 50$ deg. fahr. is $(t + \Delta t/2)$ and can be tabulated.

With the heat transfer given in Fig. 2 the arithmetical mean temperature difference (M.T.D.) is: M.T.D. $= (S \times H)/(T \times C)$, where S = steam to condenser, lb. per hr., H = heat content of the exhaust steam, B.t.u. per lb. of steam, T = heat transfer, B.t.u. per deg. fahr. per sq. ft. per hr., and C = condenser surface, sq. ft.

The steam temperature is the sum of the mean water temperature and the mean temperature difference. The corresponding vacuum can be obtained from the steam tables. The water rate is then found from the curve of Fig. 1.

The horsepower required for pumping the circulating water through the condenser is found by the use of the pump-efficiency curve, Fig. 3, which gives the efficiency of the circulating-water pump as a function of the total head. For this study the external head was assumed to be 10 ft., making the total head equal to the friction head in the condenser plus 10 ft.

Tables similar to the one reproduced were worked out for single-pass condensers with water velocities of 6.25 ft. and 8 ft. per sec. and for two-pass condensers with 4.5, 6.0, and 7.5 ft. per sec. water velocities in the tubes.

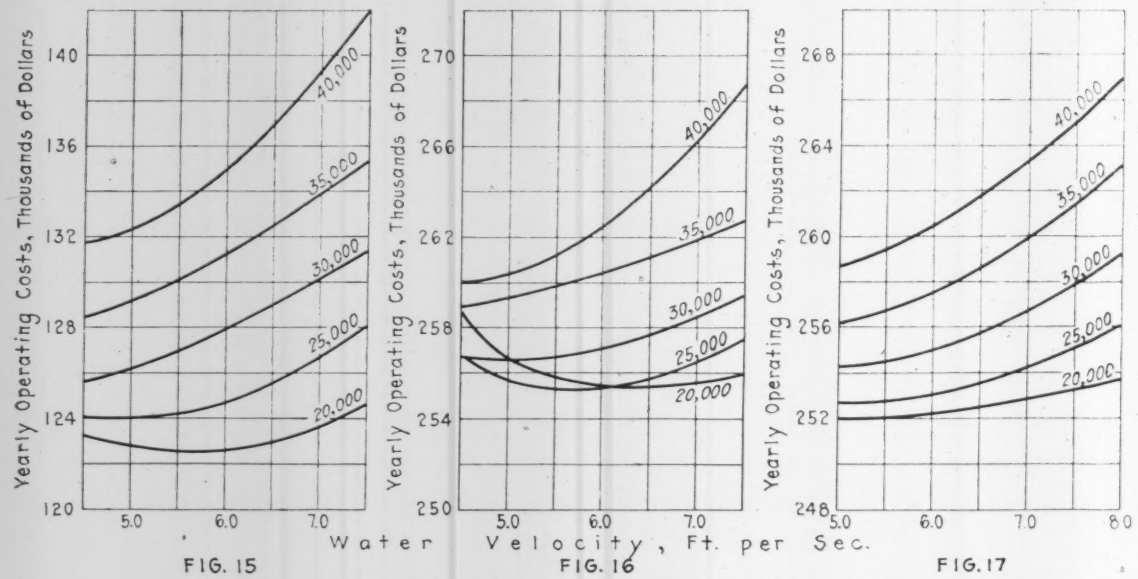


FIG. 15 FIG. 16 FIG. 17

Fig. 15 Two-Pass Condenser, 50,000,000 Kw-Hr. Yearly Output.

Fig. 16 Two-Pass Condenser, 100,000,000 Kw-Hr. Yearly Output. Straight Steam-Consumption Line.

Fig. 17 Single-Pass Condenser, 100,000,000 Kw-Hr. Yearly Output. Straight Steam-Consumption Line.

FIGS. 15–17 YEARLY OPERATING COSTS AT VARIOUS WATER VELOCITIES

(Based on 26,000 kw. load; 233,000 lb. steam condensed per hour; 50 deg. fahr. inlet water temperature; ⅞-in. O.D. tubes.)

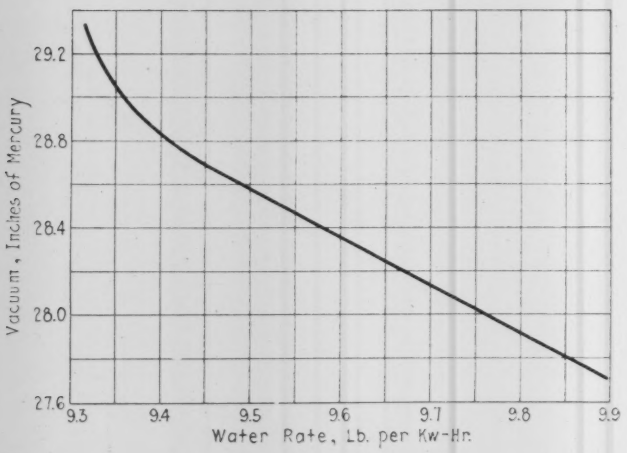


FIG. 18 WATER RATE WITHOUT BLEEDING AT VARIOUS VACUUMS (26,000 KW. LOAD)

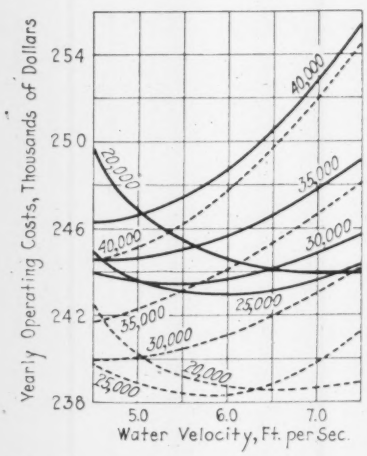


FIG. 19 YEARLY OPERATING COSTS AT VARIOUS WATER VELOCITIES

[Based on 26,000 kw. load, *non-bleeding*; 247,000 lb. steam condensed per hour; 100,000,000 kw-hr. yearly output; inlet water temperature, 50 deg. fahr. (broken lines) or 60 deg. fahr. (solid lines); two-pass condenser; ⅞-in. O.D. tubes.]

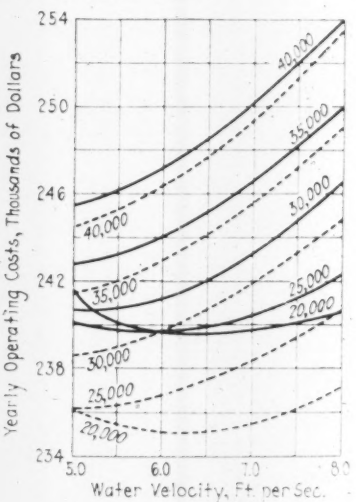


FIG. 20 YEARLY OPERATING COSTS AT VARIOUS WATER VELOCITIES

[Based on 26,000 kw. load, *non-bleeding*; 247,000 lb. steam condensed per hour; 100,000,000 kw-hr. yearly output; inlet water temperature, 50 deg. fahr. (broken lines) or 60 deg. fahr. (solid lines); single-pass condenser; ⅞-in. O.D. tubes.]

TABLE 1 CALCULATION OF VACUUM OBTAINABLE WITH CONDENSERS OF DIFFERENT SURFACE AREA

(Steam to condenser per hour, 233,000 lb.; water velocity, 5 ft. per sec.; friction through condenser, 4.2 ft.; tubes, ⅞ in. O.D.)

Surface, sq. ft	20,000	25,000	30,000	35,000	40,000
Inlet water, gal. per min	29,200	36,600	44,000	51,200	58,500
Horsepower (at 4.2 ft. friction + 10 ft.)	39.3	49.3	59.3	69	78.7
Inlet water temperature, deg. fahr	50	50	50	50	50
Discharge water temperature, deg. fahr	65	62	60	58.6	57.5
Mean water temperature, deg. fahr	57.5	56	55	54.3	53.7
Heat transfer, B.t.u. per sq. ft. per deg. fahr. per hr	352	352	352	352	352
Mean temperature difference (arithmetical), deg. fahr. (M.T.D.)	31.1	24.9	20.7	17.8	15.5
Steam temperature, deg. fahr	88.6	80.9	75.7	71.1	69.2
Absolute pressure, lb. per sq. in	1.357	1.060	0.894	0.767	0.719
Vacuum (30 in. barometer), in. Hg	28.643	28.940	29.106	29.233	29.281
Water rate, lb. per kw-hr	10.17	10.07	10.04	10.02	10.015

From the values thus found, curves for the vacuums which can be obtained were worked out. Fig. 4 gives those which can be obtained with single-pass condensers, and Fig. 5, with two-pass condensers.

The next step in the condenser study was to bring the condensers on a comparative economical basis. A yearly output of 100,000,000 kw-hr. was assumed for the calculation, and a condenser surface of 20,000 sq. ft. was taken as basis for the comparative costs.

The total operating costs consist of:

Yearly coal cost, tube maintenance, excess horsepower, coal cost, and fixed charges for the condensers with more than 20,000 sq. ft. of surface.

The yearly coal cost can be figured from the steam consumption and boiler efficiency with a given coal price.

The tube maintenance is considered only on condensers with more than 20,000 sq. ft. of surface, as this was taken as a basis for the comparative cost figures. The maintenance costs are figured in cents per square foot in excess of 20,000 sq. ft.

The excess-horsepower coal cost is found as the difference between the cost of pumping the lowest water quantity found and the cost of pumping the water quantity for the condenser in question through the condenser.

A fixed charge of 17 per cent was added for the extra costs for condensers with more than 20,000 sq. ft. of surface, assuming a condenser price per square foot of condenser surface.

The total yearly operating costs thus obtained were plotted against water velocity in the form of curves shown in Figs. 6 and 7.

The Training of Trades Apprentices

Grading System Important—Starting and Keeping Apprentices in Regular Production Departments Found Satisfactory—Follow-up of Graduate Apprentices—Value of Incentives—Selection of Apprentices—Efficient Teachers Essential, Etc.

AT THE Session on Education and Training for Industries of Non-College Type of the 1926 A.S.M.E. Annual Meeting, Carl S. Coler, manager of the educational department of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., presented a paper in which he described the methods which have been used by that concern in promoting trades training. Mr. Coler pointed out the development of incentives as an important phase of modern apprenticeship, and drew the conclusion that apprenticeship programs could be economically operated under present conditions without discounting such items as good will and the potential value of such exceptional ability as might be discovered or developed.

Mr. Coler's paper appeared in the Mid-November, 1926, issue of MECHANICAL ENGINEERING, pages 1257–1260. Generous extracts from the very considerable discussion it elicited are given below.

J. H. Bigelow,[1] who opened the discussion, said that the author, Mr. Coler, had stated very succinctly and very simply in his paper many good ideas. Some of these simple ideas had a complicated ancestry, and the course outlined by the author had been the product of many years of experience in experimentation in the particular industry in which he was interested.

Those in the telephone industries who had been interested in training men had, however, some slants different from Mr. Coler's. He had mentioned two groups of people from which industry could draw recruits. One group was made up of young men or boys who had as their chief incentive promotion in the business. The other group was actuated primarily by the incentive of wages, seeking the largest amount they could get at the present moment without any particular regard for the future.

It seemed to Mr. Bigelow that the latter group should be employed as seldom as possible—possibly they never should be employed in a stable industry unless the pressure of work was very great and the supply of those who at least gave promise of being permanent was very scarce.

Mr. Bigelow then read the following statement so that Mr. Coler might answer two questions: "A separate department charged with the responsibility of training a selected group of employees for the more responsible positions in the organization is desirable for the following reasons: "It enables the separation of the functions of production and training when the objectives sought are incompatible. It draws a definite economic and psychological distinction between the learner and the worker."

It did not seem to Mr. Bigelow that this would be a good thing. If the group in the factory or the business which did not have the opportunity for special training were given to feel that there was a definite distinction between the worker and the learner, that the learner was going to eventually get ahead and the worker was not, it was sure to result in some dissatisfaction.

Mr. Bigelow was glad that the author had brought up the point of personal attention, to which he had referred three times in the paper in different ways. At Dean Sackett's conference at the Pennsylvania State College in May, 1926, some one had been asked to speak upon this matter of introducing young college men into industry. He had said, "The way to do it is to throw them in and let them sink or swim." That seemed to Mr. Bigelow to be perhaps a little bit out of date. The idea that new employees, especially those being groomed for better things, needed better attention was certainly true. Competition for the better types of brains was increasing, and if it was desired to keep them in industries they must have some special attention.

GRADING SYSTEMS IMPORTANT

The grading system as an incentive seemed to Mr. Bigelow to be the next most outstanding one in the author's list. This must be a grading system which would take into consideration both performance in the shop and work in school, which comprised the ability to think and also the ability to perform. Those two things were the essentials in the training of men for foremanships and better executive positions in any industries.

Mr. Bigelow said he was also interested to note what Mr. Coler had not mentioned, namely, that approximately fifty per cent of all the apprentices that had been taken on by the Westinghouse Company since 1908 were still in the organization. Of that number, about forty per cent were holding supervisory positions. That meant that twenty such men out of each hundred taken on since 1908 were still in the company and were doing supervisory work. That in itself proved the success of the plan that had been adopted by the Westinghouse Company.

Mr. Bigelow then explained something about the work that was carried on along parallel lines by the New York Telephone Company. This company had graded schools in the plant departments. The same kind of young men needed by Westinghouse were likewise needed in the telephone business. They were about the same age, got about the same kind of training, and had the same potentialities. They came into the plant department at about the same time and went through various plant schools which were graded. There were four grades and two special schools in the plant where these men might perfect themselves in the actual trade or part of the work that they were going to perform next. When they got through with the work it was compulsory that they should attend one evening school. They were told that they must attend it if they were going to stay in the business, and they must attend it on their own time. Beyond this there was a long series of schools, all of which were optional. If the man had the stuff in him and wanted to get ahead, if he wanted to be a supervisor or foreman, he could keep on attending these schools. They were of increasing intensity until the time when in his work as well as in his study he got to the position of a supervisor. When he reached that point he might be a member of a foreman-training group where the personnel policies and ideals of the company from the standpoint of supervision were set before him.

If he wanted to go still further he might be assigned by his department to a special course which the company had been running for some five years for the training of college men and also other

[1] New York Telephone Co.

men who come up through the ranks. Here he got a picture of the company's business from the broader viewpoint.

As soon as that course had been begun there had been immediate requests from a great many men already in the company to make the material available to them. At the present time the material was in lecture form and a course was being run with over 7000 registrants. A new opportunity for further education had recently appeared in the Telephone Company's out-of-hour courses. These ran from five to six in the evening and were open to the whole personnel of the company. If young men who had started at the bottom as splicers, helpers, repairmen, etc., wished to study transmission, the theory of probability, etc., this enabled them to do so. These courses would fit such men for responsible jobs and broaden their mental training as well. These statements proved that while the Telephone Company was going at the problem in a slightly different way than Mr. Coler had described, this company was nevertheless in accord with this idea of progressive training which followed the man through, gave him personal attention, and made it possible for him to realize the best that was in him.

J. E. Goss[2] contributed a written discussion in which he called attention to the fact that the author had dealt with methods which had been found effective in "adjusting the old apprenticeship system to modern conditions." This might well be transposed to read, "adjusting the old apprenticeship conditions to a modern system," for it seemed to be a fact that whatever slump there had been in apprenticeship had been largely due to the lack of system. At any rate it was essential that the backbone of the old idea be retained—the learning by doing, and by repeatedly doing, regular shop work. It would be disastrous to modernize apprenticeship to the point of losing sight of this fundamental.

The Westinghouse policy of hiring rather than laying off apprentices during slack periods showed sound reasoning, but it seemed to Mr. Goss that it presented a rather delicate personnel problem. Faithful and efficient employees of long standing and with financial obligations which could be met only by way of regular employment might see it as unfair to be laid off, while young men living at home were retained, or even hired. Furthermore, work of instructional value must always be provided for apprentices. It would be unwise simply to have them put in their time at cleaning machines or other similar work. On the other hand, it must be admitted that there might be a dearth of graduates at a time when trained men were badly needed.

Starting and Keeping Apprentices in Regular Production Departments Found Satisfactory

The question as to whether work in a production department should be preceded by work in a training department could be argued, but starting and keeping apprentices in regular production departments always had worked very satisfactorily with the Brown & Sharpe Mfg. Co. Their success in this regard was due in considerable measure to the importance which the management placed upon apprenticeship (an attitude which was well known by their foremen and sub-foremen), and to the fact that many of the leaders with whom the apprentices came in direct contact were themselves graduates of courses and had a real appreciation of their apprenticeship system.

By putting apprentices directly into a production department, several purposes were accomplished at the Brown & Sharpe plant. The young man immediately got into a shop atmosphere, which was just the thing he desired; he promptly learned the value of production, an essential factor in shop work; he got the benefit of instruction not only from the foreman and the shop instructor, but from experienced workmen about him; and he had a better opportunity for piecework. It was known that some people offered serious objection to piecework for apprentices. Perhaps there would be skepticism about it, were it not for the fact that it had been found at Brown & Sharpe's over a period of years that piecework could be given to apprentices primarily as a means of teaching the value of production. Only incidental to this purpose was the increased wage. In some of the departments on the apprentice schedule piecework would not mix well with the learning process, so it was not given there. Those in charge did not recall a single complaint or difficulty resulting from this plan.

[2] Brown & Sharpe Mfg. Co., Providence, R. I.

In recalling that the author had mentioned that a representative of the training department visited each apprentice from time to time, Mr. Goss wrote that this was an important phase of apprenticeship. Both the foreman and the apprentice liked to feel that there was some one connected with the Apprentice Department to whom they could readily turn on apprenticeship questions. Brown & Sharpe employed a man who devoted all his time to apprentices in the machine shop and foundry. He acted in the machine shop as an instructor and adviser, and in the foundry as adviser only. In the pattern shop a man was assigned as a part-time instructor. To him as well as to the foreman the apprentices might take their problems. In the drafting department instruction was by the leading men, most of whom were graduates of the drafting course. All transfers on the apprentice shop schedules were made by the Apprentice Department. This also was important in the conduct of apprenticeship, it was believed.

In referring to the Westinghouse system of time allowances for those obtaining so-called "A" and "B" grades, Mr. Goss wrote that he understood that the grading was done every ten months and that an "A" grade carried an allowance of three hundred hours. Assuming that a young man maintained an "A" grade throughout his four years of apprenticeship, he would earn a total allowance of about six months. Instead of time allowances, the Brown & Sharpe Mfg. Co. made pay allowances for excellence. Time allowances had been given in a few cases to high-school graduates who had stood high in the courses. Possibly they had been a little too conservative in this respect, for it did seem that such an allowance might make an apprenticeship somewhat more attractive to a young man eighteen years of age who already had spent four years in a high school or trade school.

Follow-Up of Graduate Apprentices

Mr. Goss was pleased to note what the author had said about the follow-up of graduate apprentices. There were some who might believe that a young man who had served four years in the shop should be expected to show initiative enough to make his own way in the organization. Although Brown & Sharpe did not object to their graduates coming forward with their reasons for promotion, it was the company's business to anticipate such action and to feel certain that no one had been lost sight of. Unless there was some systematic check-up, good material might be allowed to go to waste in obscurity. The quarterly check on graduates was turned over to the works superintendent by the Apprentice Department and contained all the information which the superintendent needed in judging whether or not the graduate was in the best position for both the company and himself.

The author said that the meeting at which the apprentice certificate was awarded afforded an opportunity to talk over plans for the placement of the graduate. Mr. Goss believed that it was a good plan to make at least tentative placement before graduation; to allow two or three months just prior to graduation for specialization on the work at which the graduate probably would be placed. He mentioned the Brown & Sharpe interview system as very helpful. Periodically during a young man's apprenticeship he was interviewed by one of the executives, who made a written report to the Apprentice Department. To some extent this obviated placement on a job to which the apprentice might lean only momentarily. The specialization helped in overcoming a false start as a journeyman.

One of the biggest problems, as Brown & Sharpe saw it, Mr. Goss wrote, was to obtain good apprentices. Brown & Sharpe took only a small percentage of the applicants for apprenticeship. Seldom was the young man who dropped in from the street at all interesting to them. General publicity brought a few desirable young men; bulletins in the shop drew the sons and relatives of employees—and this was a good way to get apprentices; coöperation with high schools and vocational-guidance agencies brought a very small percentage of young men, usually very good material.

D. E. Carpenter[3] wrote that the author assumed that the need for apprentice training to be well recognized, was an assumption that was correct when applied to progressive management. Unfortunately there were still many concerns that failed to recognize this need fully,

[3] Dean of the Faculty, International Correspondence Schools, Scranton, Pa.

but the number was constantly growing less. The days when more thought was given to selection of machines and materials than to the selection and training of operators had passed.

The reason for the distinction between "skilled artisans" and "machinists" in the vocational classification of fathers of trade apprentices, however, was not clear to Mr. Carpenter and he questioned whether it was intended to exclude machinists from the general classification "skilled artisans," and what vocations were included in this latter classification.

VALUE OF INCENTIVES STRESSED

Among the headings under which details of the plan were discussed, the most important seemed to Mr. Carpenter to be incentives. The law of inertia of matter had a close counterpart in the characteristic of humanity to be content with existing conditions until some incentive impelled improvement in those conditions. Men were not all Franklins or Lincolns; the innate desire to learn simply because of the desire to know did not impel all to exert themselves for self-improvement. There was need for mental stimulants of the kind listed by the author.

If the desire to learn could be made strong enough, any individual of ordinary natural ability would make the most of every opportunity and was likely to excel even with mediocre advantages. A good apprentice system with unattractive incentives might be successful with some apprentices, but a system was sure to succeed with many if the incentives were such as to inspire best efforts.

E. E. Sheldon[4] remarked that it was now plain that the old system of master and apprentice had no place in modern industry. He also brought out the fact that in addition to giving training and broader opportunities to able young men, the new systems of apprenticeship gave incidental training in thrift, safety, and economics which was of great value in the efficient maintenance of an organization.

Mr. Sheldon said that the Lakeside Press (R. R. Donnelley & Sons Company) of Chicago had been carrying on a training program under his direction for eighteen years, having at the time of this discussion had about 300 boys and young men in training in three different plants. Eighty per cent of those trained had remained in the employ of the company, and of these twenty-five per cent were in executive positions.

John A. Randall[5] analyzed the author's statements with a view of locating facts to influence company policies toward trade training and also for significant elements in the technique of apprenticeship training.

Mr. Randall said that while Henry Ford in his book Today and Tomorrow stated that he had a limitless demand for toolmakers, there were still many managers who were not yet convinced that it paid to set up apprenticeship systems. He therefore called for more facts if more were needed for conviction. The idea of coördinating training records with personnel records appealed to him as good practice. Among the several things in the Westinghouse program worthy of close study he cited morale and incentive.

David L. George[6] wrote that, in the main, the author's description of the Westinghouse apprenticeship system coincided very closely with that of the system at the Erie Works of the General Electric Company. The only pronounced differences were in the method of operation of the Trades Apprentice School, in the method of selection of apprentice candidates, and in the employment of incentives.

Under the General Electric plan classroom instruction was confined to the preliminary period during which the apprentices were in the training room. Four-year apprentices remained in the training room for the first eighteen months. The three-year apprentices (high-school graduates) spent their first year in the training room. It had been found under an older system that the foremen in the shop were very much opposed to apprentices because their frequent absences to attend school disrupted production schedules. Thus it was difficult to place apprentices in some departments where they could obtain excellent experience. Even if they could be placed in one of these departments, the foreman was reluctant to assign them to work which was of desirable type for training the boys. Under the new system the foreman was willing to accept his responsibility and coöperate with the Apprentice Department in the training of his future skilled mechanics.

Pedagogically, this method of intensifying the classroom work into the earlier part of the boy's apprenticeship might be wrong, but this argument was more than offset by the fact that apprentices were allowed and encouraged to continue their technical education by attending the Technical Night School. There the apprentice could undertake the four-year engineering course without payment of tuition fees.

The success of any apprenticeship system, Mr. George wrote, depended greatly upon the caliber of the apprentices. One could perfect the training programs, utilize the most modern types of machine tools, pay attractive wage rates, supply adequate forms of technical education, but unless apprentice departments were composed of bright, ambitious, industrious, and substantial boys, no system would produce good results.

FACTORS ON WHICH GENERAL ELECTRIC COMPANY BASES SELECTION OF APPRENTICES

In order to obtain the best talent possible, the General Electric Company based its selection upon the following factors:

1 Results of a mathematical examination
2 Results of a mechanical and mental test
3 Examination of the applicant's school record
4 Examination of character references.

This might not prove to be an infallible method of selection, but the three months' probationary period afforded another opportunity to measure the ability and adaptability of the applicant.

As an aid in recruiting the best possible talent, talks were given by members of the educational staff to the student bodies of local high schools, city and rural, and to parent-teachers' associations. Excellent results were achieved from this method of advertising the apprenticeship plans, the best material coming from those high schools where they had been granted the privilege of explaining the work.

The benefits derived from the establishment of incentives for the apprentice had been noteworthy. The following incentive plans were in vogue at the General Electric works:

1 Periodic wage increases
2 Grading apprentices into two classes, A and B.

A class A apprentice was one who satisfactorily completed his school work in the prescribed period. A class B apprentice was one who failed to meet this requirement but could change his status if he completed his regular school work at some future date through attendance at night school or through any other agency.

Class A apprentices were paid 2 cents per hour more than the regular rate.

3 Apprentices who obtained grades of 95 per cent or better in their school work in any term were awarded a cash bonus of $20.

4 Apprentices when employed in the manufacturing department, might participate in the piece-rate premium or bonus plans effective in that department on the following basis:

Second year, 60 per cent of journeyman rate
Third year, 70 per cent of journeyman rate
Fourth year, 80 per cent of journeyman rate.

5 Any outstanding apprentice at the time of his graduation was recommended for one of the Chas. F. Steinmetz Memorial Scholarships at Union College.

J. C. Wright[7] contributed a written discussion in which he agreed with the author that the training of apprentices for the skilled trades was essential if it was expected to keep up the supply of skilled workers in America. The immigration laws had to a large extent cut off the supply of skilled workers from Europe, and unless a definite program of apprenticeship training was carried on for all manufacturing and mechanical pursuits, the time would come when skilled workers could be had only at a premium.

Mr. Wright then undertook to point out various phases of the

[4] Supervisor of Training, The Lakeside Press, R. R. Donnelley & Sons Company, Chicago, Ill.

[5] President, Mechanics Institute, Rochester, N. Y. Mem. A.S.M.E.

[6] Supervisor of Education, General Electric Company, Erie, Pa.

[7] Director, Federal Board of Vocational Education, Washington, D. C.

program as outlined by Mr. Coler which might be made more efficient.

He wrote that a great deal of research work had been done in attempting to determine the efficiency of the various aptitude and intelligence tests and the degree of correlation between a person's rating on an intelligence or aptitude test and his general ability to perform successfully the duties required in his trade or occupation. A certain company employing several hundred apprentices had carried on a series of experiments in checking the rating of the apprentices on the Otis intelligence test with the rating given by the shop foreman. This company had found approximately an eighty per cent correlation between the rating on intelligence tests and the rating given by the foremen. Other experiments of this type had not shown so high a degree of correlation between the tests and the actual ability of the boys to do satisfactory work in the trade or occupation, and it was evident that, although the tests had some value, they should not be relied upon entirely in determining a boy's fitness or unfitness to be trained successfully for a skilled trade or industrial occupation. It seemed to Mr. Wright that the test in arithmetic as suggested by the author would indicate the efficiency of instruction in mathematics in the schools the boys attended rather than their ability to receive instruction in the trade, and that, although this test might have some value, it should not be relied upon entirely in the selection of apprentices.

Efficient Teachers Essential

The use of expert workers from the various departments as instructors assured that the instructors were competent in the subjects they expected to teach. It did not assure, however, Mr. Wright pointed out, that these instructors were able to teach efficiently. In other words, they might be fully competent to perform their jobs but not competent in teaching others to perform them. A teacher must not only know his own trade but must also know the teaching trade. In other words, he must not only have knowledge and skill but he must be able to impart this knowledge to others.

Mr. Wright's own experience in vocational education had indicated that the most competent men in their trade or occupation were often the poorest instructors because they did not appreciate the difficulties of the learner in acquiring the necessary knowledge or skill and they had no training in organizing teaching material and in methods of instruction.

In the public vocational-education program special provision was made for the training of skilled workers to teach, and the importance of this had been so clearly recognized that the National Vocational Education Act had made special provision for the training of teachers and instructors of vocational subjects. This provision of the National Vocational Education Act required that all states using federal funds for vocational education must also make special provision for the training of teachers whose salaries were paid from these funds. In the case of trade and industrial education, skilled workers who were chosen as teachers were given special professional training in trade and job analyses, organization of teaching material, and methods of teaching.

The experience of the Federal Board of Vocational Education indicated that, although a worker might be thoroughly proficient in the performance of the jobs in his trade, he might still not be a satisfactory worker due to the fact that he seemed to be either unwilling or unable to fit into the organization in which he was working. In other words, the worker's attitude toward his work, toward his superiors, associates, and subordinates, was as important, if not more important, than his ability to perform the operations and processes in his trade. An unfavorable attitude of a worker was often due to a lack of clear thinking on his part as to his duties and responsibilities not only for performing his job but in fitting into the organization in human relations, in other words.

Training in human relations had been carried on for foremen and minor executives through foremen conferences and it seemed just as important that training in human relations be carried on with apprentices, if the apprentices were expected to make the most of their training in skill and technical knowledge. This work could probably best be handled, Mr. Wright believed, by the conference method, in which the apprentices would be given an opportunity to discuss cases and think through the problems in human relations with which they were confronted.

W. E. Wickenden[8] said that it was exceedingly important to every division of technical education that every other division should be vigorous and well developed. If we were to have good engineering education we must have good industrial education, and if we were to have good engineering education and good industrial education it was equally true that we must have good technical education, which in point of time and scientific content lay somewhat intermediate between these two extremes of the scale.

Mr. Wickenden, as one who had been a close student of engineering education in this country for some years past, said that the conviction had been forced upon him that we had been concentrating too large a proportion of our efforts educationally at the particular end of the scale occupied by the engineering college. We had thereby gotten top-heavy and unbalanced systems, and the engineering colleges themselves suffered in their efficiency from the resulting confusion of aims and of methods and objectives. Perhaps nothing was more needed for the betterment of engineering education than a clearer definition of aims and functions, a more intelligent sharing of the field with other forms of technical education such as the author had presented.

Author's Closure

The author, Mr. Coler, then closed his discussion. Referring to comments by Mr. Bigelow, he said that the business side must be considered in connection with the training of men in industry. There was one group of men in industry which might be considered the backbone of industry. This group was always present, growing up and staying in that industry. There was another group which came and went to take care of extraordinary conditions, and it might be said that in this country extraordinary conditions always existed. It had been to bring out the connection between the business cycle and the training program that Mr. Coler had divided the personnel of an organization into these two groups.

It was necessary to keep out as much as possible the group which entered only when extraordinary conditions existed. All organizations were therefore trying as much as possible to stabilize themselves and to get a straight-line production which would greatly help out the training program.

The objectives which were incompatible between the young man in apprenticeship training and the regular employee were naturally the educational objective and the production objective. There were times when the immediate interest of the foreman from the standpoint of production was antagonistic to the best training and development of the student, when the apprentice was under an apprenticeship department. This matter was better taken care of if the foreman was left to make the final decision for himself between the regular man and the student. Regarding the difference in attitude toward the student and the regular workman, Mr. Coler said, there was a fundamentally different economic status. When the apprentice was paid a smaller rate, it was necessary to give him the benefit of better training. The instruction that he got was the compensation which made up for the lower rate.

Mr. Goss had raised several significant points, Mr. Coler said, such as in regard to retaining the apprentice during dull periods. There were two ways of looking at that problem. One was from the standpoint of the apprentice. He was paid a low rate which did not give him much chance to lay by a surplus. If his employment was made uncertain, an injustice was done him.

A second point was that if apprentices were laid off during dull times, very few trained men might come along normally during the time that they were needed. In an average plant, the number of apprentices was not large compared with the total number of employees, hence it should be possible to bring in enough to keep the apprentices busy on productive work during dull times.

A separate department depended to some extent on the number of apprentices to be trained. It was well to put the new apprentice in touch with the best instructors and foremen who understood thoroughly the psychology of new men, and then put him out into the shop after he had had the first part of his training in this special

[8] Director of the Investigation of Engineering Education for the Society for the Promotion of Engineering Education.

department. Thus he would ultimately get the contact with workmen. The regular swing of production was obtained under special conditions in the training department if he was working on productive work at the same time.

Mr. Coler said that the meetings which were held at the conclusion of the apprenticeship period at which the certificate was given to the apprentice gave a splendid opportunity for foremen and superintendents to understand the apprenticeship work. By asking the boys questions about what they had been through and what they were going to do, a clear understanding in this development of an apprentice program was given to the strategic men.

In reply to the question, "Is there a real need for trades training?" Mr. Coler said that according to a great deal of literature that had appeared recently there was not enough trades training. Most of the writers had spent most of their efforts in showing why there was not enough training rather than in showing how to do more.

As to the cost, it was possible, Mr. Coler believed, to nearly break even on a trade-apprentice program, if the details were watched and the resources of the plant were used to the best advantage.

The problem of selection was important, but it was much more important to have a large number of candidates to select from than it was to know how to select and have no applicants.

It must be taken into consideration that the young employee from sixteen to twenty must be dealt with in an entirely different way from the older employee of from forty to fifty. The foreman or executive who treated both groups in the same manner was sure to have a high turnover at one end or the other. The psychology of the young man demanded that things be kept shifting for him. If not, he would shift them for himself. If a study were made of any organization that took in a number of boys and put them on routine jobs and kept them there, one would find nature trying to get around that condition by making the turnover high. In other words, the apprentice would try to get his broadening experience in different plants instead of in different parts of the same plant.

In reply to the question, "Can an apprenticeship system be applied under different conditions in the same way?" Mr. Coler said that the fundamentals were about the same, but an apprenticeship system must be started in the same way as a seed and allowed to grow to suit its environment.

During the war period apprenticeship systems picked bodily out of some other conditions had been installed in many plants. Most of those systems were not existent today. One must start with a small number of boys and gradually let the system grow to suit the needs.

The mathematical test in conjunction with an interview had been found very satisfactory for weeding out the men who were below the requirement for trades training. The interviewer could also profitably touch such things as personality, stature, health, and, to some extent, intelligence.

Mr. Coler said that he devoted the early morning hours (7 to 9) to classroom work for trades apprentices before they had got their hands dirty and before they had used up their "pep." Later on in the day the same classrooms were used for high-school boys, and still later on, for the college men.

Organization—Railroad and Industrial

AT THE second of the sessions on management held during the 1926 Annual Meeting of the A.S.M.E., two papers were presented dealing with problems of organization. The first, by J. C. Clark,[1] on Railroad Organization, defined the terms "administration," "organization," and "management," and dealt with fundamental differences distinguishing the railroad industry, methods of controlling business, functional organization, methods of organization, coördinating the work of various departments, etc. The second, by Robert E. Newcomb,[2] and entitled Vitalizing vs. Centralizing Organizations, enumerated the disadvantages of concentration and the advantages of discreet decentralization. A summary of the discussion appears below. The papers themselves were published in the Mid-November, 1926, issue of MECHANICAL ENGINEERING, pp. 1247–1252, inclusive.

RAILROAD ORGANIZATION

Discussing Mr. Clark's paper of the above title, Hayes Robbins[3] wrote that it described very clearly railroad organization at the present time. The question whether it was capable of improvement, and in what respects particularly, was of major practical concern, looking to the future. Mr. Clark discusses several alternatives and possibilities, but his statement that the human organization had not kept pace with mechanical development, might properly be emphasized as of fundamental significance. Mr. Clark has also said that today the great opportunity for advancement lay in the careful study of organization, the analyzing of every official and non-official position to see what type of man could best fill the given positions, and then selecting and training for the work.

Such a program, in railroading particularly, was complicated by the deeply rooted seniority procedure, but there were no doubt many possibilities of the nature indicated not yet utilized. It had obviously not been Mr. Clark's present purpose to develop further what was in fact a large subject in itself.

Nevertheless, it might be suggested as highly pertinent that the need for a higher valuation of latent human resources extended into every cranny of the organization machine. It offered more varied possibilities of constructive action than were here indicated. In addition to the placing of the right men in the right positions and the proper training for assigned duties, there was before us with a growing insistence the whole question of effective morale in the sense of voluntary response to legitimate incentives, recognized and furthered through organization in its varied forms. Primarily these were questions of policy rather than of organization, per se, but organization should make definite provision for their proper functioning and development.

Here was involved a study of methods and measures which were found in experience to bring us nearer to such objectives, among others, as (*a*) better understanding throughout the personnel at large of the problems and policies of the management and conditions of the industry, (*b*) better knowledge and consistent application of sound principles of supervision, (*c*) provision of educational opportunities for improvement in individual effectiveness, both of supervisors and wage earners, with its direct bearing on the man's interest in his occupation, and (*d*) encouragement of suggestions and more direct contacts of management with the working forces, to the end of a better assured confidence and sense of common responsibility: in brief, the building up of what one of our well-known railroad presidents[4] had described in a recent annual report as "a service distinguished by voluntary interest and good will rather than a mere perfunctory discharge of assigned duties."

These objectives directly affected the functioning and productive results of organization, however planned and coördinated. They had also a profound relation to the character of the general environment in which public-service enterprises were carried on and upon which they depended. Railroad managements might well give systematic study to the opportunities within this field, and profitably exchange experience in the promising developments already under way.

While these matters were not directly within the scope of Mr. Clark's discussion, they were perhaps legitimate extensions of the thought underlying his premise that the human organization had not kept pace with mechanical development.

[1] With Industrial Relations Counselors, Inc., New York, N. Y.

[2] Superintendent, Deane Works, Worthington Pump and Machinery Corporation, Holyoke, Mass. Mem. A.S.M.E.

[3] Newton Center, Mass. Formerly Assistant to President, B.&M.R.R.

[4] J. H. Hustis, former President, Boston and Maine Railroad, in Annual Report for 1924.

Vitalizing vs. Central Organization

Wooster W. Webber[5] wrote that a study of Mr. Newcomb's paper on this subject revealed to him that in an attempt to create a vitalized organization from a centralized one, an exceedingly heavy burden fell upon the initial executives. Thus, the training of future executives over a considerable number of years as subordinates handling details and minor responsibilities was necessary before they in turn could throw off these details to others and still be cognizant of their importance. And during this initial period of years the important element of morale must be developed and maintained, otherwise the company trying to establish such a control would be without its subordinates to train. This threw a double burden of detail on the executive who attempted the change; that was, he must select and train his personnel and, at the same time, develop a morale which would be contagious among them. When once such a control had been established, little fear for the responsibility of detail need be felt by the executives because that acme of morale—loyalty—had been attained through the employees. It was probably for this reason—the dual load imposed—that so few plants had established a vitalized control, it being principally found in combinations of existing plants.

John C. Robinson[6] wrote that in general, he agreed heartily with Mr. Newcomb's conclusions but, as in anything else, judgment had to be used in applying them.

Every successful business was a dynamic, not a static thing. If it was static, it was dead. Centrifugal and centripetal forces, the diffusion or concentration of authority, were always at work and must be balanced by intelligence. As Mr. Newcomb said, personnel was of first importance.

In Mr. Robinson's estimation there was no greater pleasure in life than dreaming dreams and then trying to make them come true. Nothing else so stimulated interest and effort. Unless the executive was willing to delegate responsibility, he was denying this pleasure to his staff, checking their interest and enthusiasm and robbing his business of the ability for which it was paying. If authority was delegated, it should be real authority. Suggestion and help should be given, but there must not be constant nagging and interference.

Opportunity for initiative must be afforded and credit given, but dynamic leadership was equally essential and many a concern today was dry rotting from its lack.

One trouble with a good many executives today was that they took transactions altogether too seriously.

Personnel, training, organization—all were necessary, but everything depended on a leader endowed with vision, tact, and good common sense.

Frank A. Buese[7] wrote that an industrial organization should enable a major executive to develop the powers of his subordinates without excessive friction between them and yet have his policies followed by every one in the organization. Tools of management which had been developed to accomplish these ends included:

1 Standardization of materials and parts used in products and in tools, buildings, machines, and other manufacturing equipment. Thus a degree of centralized control was obtained over inventories, loss through obsolesence, and quality and cost of materials. Engineers at all works were required to exercise their judgment in selecting items from the standard list. They should have a voice in fixing and revising standards. They could improve products instead of spending valuable time securing data on materials, since such information was given them by the standard specifications.

2 Standardization of methods. Thus, definitely fixing the general routine for handling and recording stores materials, prevented carelessness and loss of materials, and increased the accuracy of accounting reports. Subordinates should be consulted in selecting a general method which would apply to all works. Standardized routine required a man of less ability than one who must meet widely varying conditions. The recorded methods should use the valuable but unwritten experiences of men long in the service. What had been said of routine was also true of manufacturing methods. The ability of subordinates was developed by their efforts to accomplish the object set by the standard method.

3 Budgeting, which enabled an executive to control production, expense, sales, and profits; and very decidedly developed in subordinates all qualities necessary to attain a given goal.

4 Standardization of cost elements such as wages, and complete costs of products or parts. This also provided centralized control and developed subordinates ability.

5 Specialization. Because all elements of manufacturing were now studied much more in detail than 50 years ago, men of exceptional ability now headed large departments which formerly did not exist. Chief tool designers and metallurgists were examples. On the other hand, the man who formerly had insufficient knowledge of details to be a foreman even though he had executive ability, could now be a foreman or shop superintendent, because he was not required to be a tool expert, employment agent, cost accountant, storekeeper, and rate setter.

Some companies were using these and other methods to obtain the advantages of both centralization and decentralization.

G. E. Schull[8] said that he quite agreed with the thought on vitalizing an organization, but it appeared to him that there still persisted a considerable amount of confusion on the matter of centralizing. Very often those in an organization when centralizing were likewise decentralizing, and he thought that that part should ever be kept to the fore; the matter of vitalizing could be carried out in a scheme of centralization and decentralization.

[5] Sales Engineering Dept., Hyatt Roller Bearing Co., Worcester, Mass. Jun. A.S.M.E.

[6] Treasurer, Connecticut Valley Realty Co., Springfield, Mass. Mem. A.S.M.E.

[7] Standardization Dept., Fairbanks, Morse & Co., Beloit, Wis. Jun. A.S.M.E.

[8] Organizer, Linoleum Division, Armstrong Cork Co., Lancaster, Pa. Mem. A.S.M.E.

The Wrought Light Alloy "Lautal"

LAUTAL is a ternary light alloy; it contains 4 per cent of copper; 2 per cent of silicon, and the remainder is made up of aluminum of commercial purity, containing iron up to the usual maximum. After casting, the metal is thoroughly worked by rolling or pressing, which process imparts high strength to the resultant material. The alloy may then be brought up to its maximum strength by quenching it at 486–500 deg. cent. and following this up by heating in an oil bath for 16 hr. at 120–130 deg. cent.

The alloy is produced by Messrs. Lautal-Walzwerk B.m.b.H., Bonn-on-Rhine, Germany, who supply four grades of the material. The "unhardened" quality is the quenched but untempered, i.e., unaged, variety. The minimum tensile strength of this is given as 19 tons per sq. in. and the maximum as 22 tons. The elongation varies between 18 and 25 per cent, and the Brinell hardness number from 70 to 80. The "normal" quality is the quenched and tempered, i.e., fully aged variety of Lautal. The ultimate stress of this is stated to lie between 24 and 26.6 tons per sq. in., and the yield point between 13.7 and 17 tons. The elongation is identical with that of the unhardened quality, and the Brinell number varies between 90 to 100. The third grade, termed the "soft annealed" quality, is obtained by annealing either the unhardened or the normal materials to a temperature lying between 350 and 400 deg. cent. for a short time. Its tensile strength is given as 14.6 tons, and the Brinell number as 50 to 55; the elongation ranges from 20 to 28 per cent. This latter condition is the most suitable for deep drawing operations; moreover, should the material become work-hardened, it may be softened repeatedly by further annealings. When the drawing operations are finished the material may be brought into the normal condition by the usual quenching and tempering processes. Sheets of hard-rolled Lautal are also produced; in this condition the material is very hard and brittle. The tensile strength is increased to a maximum of 38 tons per sq. in., but at the expense of the elongation, which ranges between 3 and 15 per cent. The hardness number is given as 100 to 135. The deterioration-resisting properties of the aged alloy are apparently equal to those of other aluminum alloys of similar type. The material combines lightness with high strength, and the producers advocate its use for the structural work of aircraft and for the manufacture of forgings, stampings, and rolled products for the motor-car and allied trades.—*Engineering*, Feb. 4, 1927, p. 133.

Opportunities for the Engineer in Industries

The Engineering Problems Involved in the Installation and Operation of Moderate-Sized Factory Power Plants—Services That an Advisory Engineer Can Render in the Selection of Equipment and in Improving Operating Conditions

By ARTHUR SCRIVENOR,[1] RICHMOND, VA.

THE purpose of these notes is not to enumerate the many things an engineer may do and to say how he may do them; rather it is to touch on some of the opportunities for engineering in the factory, and particularly in the factory power plant of small size, leaving it to the engineer to develop them.

The factory owner is busy watching the market, improving production, adjusting labor conditions, or attending to dividends. He has little time in which to go outside to learn what others are doing, to investigate new methods or equipment, or to search out the losses, possible improvements, and greater earning power in his own plant.

Most concerns employ an engineer, of one type or another. Some are employed solely to design, install, and maintain. Others are engineer-managers or superintendents. Still others are operating engineers. Those of the first class are skilled in the art to which the processes of manufacture in which they are interested are related; but they are ready and willing to consider suggestions made by others, and so possibly to learn of something which may have previously escaped their attention. Those of the second class are skilled in their art; but their managerial duties are such that they, like the owner, are principally concerned in the processes and business which they conduct. Those of the third class are skilled in the operation of the machinery and equipment of which they have charge, but they are not as a rule sufficiently conversant with such questions as costs, labor, production, combustion, heat, etc., to be in a psition to advise their employers, or to know whether the plant is being operated to the best advantage or not. Many plants are being operated by business men, with the assistance of engineers of the third class; and these business men devote much of their own valuable time to the consideration of engineering questions. If they do not, many important questions are left unconsidered, and the best results are not obtained.

In plants where engineers of the first and second classes are employed the advisory engineer is often welcome, and can give assistance in checking up present conditions or by offering suggestions which may lead to still better results; but it is in plants where engineers of the third class only are employed that the advisory engineer can be of particular service.

It is not possible for an outside engineer to enter any plant with which he is not at all familiar, and successfully plan improvements without the coöperation of the officers; for it is certain that the owner and his assistants know the facts in connection with the present costs of material, labor, production, operating expenses, results, market, and finance better than can a newcomer. But it is not certain that they know all the facts, nor all of the possibilities; for their attention is chiefly occupied with existing and visible conditions; and for this reason, in one field or another, and with the coöperation of the departments concerned, the advisory engineer can be of service.

An improvement is not an expense. An investigation may or may not result in an improvement; and it may be an expense if it discloses the fact that, for one reason or another, no improvement can be made. But even then it cannot be considered a dead expense or waste, for at least the owner has received disinterested testimony to the fact that he is doing all that is reasonably practicable; and he may be able, with an easier mind, to turn his attention to other details of his business.

The Advisory Engineer a Valuable Aid in the Case of a New Plant

In the case of a new plant—a plant about to be built—the advisory engineer can give valuable aid. The owner is confronted with problems such as: How much power do I need? How much power shall I need in the future? How much heat do I need for heating the factory and for process work? What form of power shall I use? Shall I make my own power? Shall I buy all or a part of it from the central station?

If it be decided to install a power plant to care for all or a part of the power needs, it is necessary to determine what will be the most economical type and size of plant; and if it is to be a steam plant, what type of boilers, of prime movers, and of auxiliaries shall be installed. These are questions which are sometimes answered without an investigation of conditions.

Important factors affecting the selection of a boiler plant are the nature of the load, water, fuel, and labor. The quality of the water, and its treatment to prevent scale perhaps, have a bearing on the preferred type of boiler. The class and quality of the fuel have a bearing on the type and dimensions of the setting, and upon the type of furnace. The load is more easily carried by one type of boiler than by another. There is or there is not a supply of skilled and reliable boiler-room labor.

Other important considerations are the space available, coal handling, ash disposal, hours of service, reserve units, the pressure to be carried, the use of process steam, the living conditions of the boiler-room force.

There are also the questions of initial cost, cost of operation, cost of maintenance; and neither last nor least is the question, Which type and class of plant is to be preferred under present business conditions, having in view the possibility of expansion and improvement in the future? It is not always the plant which promises a low cost of operation that is the most economical.

All of these are engineering questions, and to answer them intelligently it is necessary to make a survey of the processes of manufacture, and of all conditions. Rarely are they the same in any two plants. Each one is a separate proposition. The plant as a whole, and the coördination of its various parts, should be studied. Lack of coördination and want of regard for relative conditions are often responsible for preventable loss.

Problems of the Plant Already in Operation

With this brief sketch of some of the problems arising in the new plant, we pass to the plant already established and in operation. In a steam plant the commodity manufactured and for sale is steam; or more particularly, heat. It is desirable to produce this commodity at the lowest cost. Variable factors affecting this cost are again water, fuel, load, and labor; as well as maintenance, depreciation, renewals, etc.

In the factory proper a minute account is kept of all costs—raw material, labor, supplies, overhead—which go to make up the cost of the finished product. In many cases the only boiler-room costs kept are those of the labor and of the coal delivered—according to railroad weights. Sometimes there is found a recording pressure gage, but rarely a record of the water evaporated per pound of coal, of the steam delivered to the factory, of the total water used, of the furnace conditions, of the draft, of the heat lost to the atmosphere, of the time consumed in cleaning boilers and fires, or of the cost of steam.

Taking only one of these for example, the water evaporated per pound of coal fired, it is not commonly realized what a difference one pound of water more or less makes. In many factory boiler rooms the average evaporation per pound of coal fired is no better than six to one. Given a steaming rate of 1000 boiler hp. and coal at $5 per short ton in the furnace, the difference, in cost of coal alone, between evaporations of six and seven to one in a period of 300 days of 24 hours each is $12,860. The difference in cost of coal alone between evaporations of five (not a rare figure)

[1] Consulting Engineer. Mem. A.S.M.E.

and seven to one for the same period is $30,860. These figures do not take into account the greater cost of ash disposal, furnace repairs, labor, and other items.

The first figure given would go a long way toward improving the standard of the boiler-room operating force. A small part of this figure, capitalized, would pay for the equipment necessary for keeping boiler-room records and accounts.

THE VALUE OF RECORDS

A suggestion that records be kept is met with the remark that the factory has no one who understands about such matters, no one who could keep the records, and that even if some one is shown how to keep them and to interpret them, they will not be properly kept; and so on. In many cases this is quite true; but it is just as easy, and just as important, to keep records in the boiler room, and to interpret them, as it is to keep and interpret the records of the factory and of the treasury department. If the work is not sufficient to warrant the continuous employment of an engineer versed in these matters it is, nevertheless, important enough to warrant the continuous employment of a man having the ability to operate the plant, with the assistance or supervision of the advisory engineer. The factory engineer is often glad to have the aid of the advisory engineer to keep in view the important details of the plant, the principal sources of loss, and to check his own figures. It is well to think again how valuable the services of the advisory engineer may be, if the fuel cost of steam be improved only one point.

These are a few of the boiler-room problems. In the engine room and factory there are others to solve: the preferred types of prime movers and generators; reserve units; lubrication; steam consumption per horsepower; uses for exhaust steam; uses for process steam; the pressure to be carried; the load, and its variations. In the factory we have to consider the most economical size and type of motor; the drive, whether group or individual, belt or direct; distribution, balance, wiring, fire hazards; the design of lineshafting and belting; heating, ventilating, lighting, sanitation, etc. Here are many chances of loss. Here is a large field for the engineer; for each one of these, and of others not named, has a bearing on the cost of the product.

It is sometimes supposed by users of small amounts of power that one's problems are solved when he purchases from the central station. All one has to do is pay the bill within ten days. As a matter of fact, the same problems exist between switchboard and machine tool whether current be bought from the central station or not. Indeed, central-station service introduces one or two additional questions, such as the terms of the contract and the motor load. The question of the size of motors is quite important, not only in respect to efficiency but also when a demand charge is based on the installation. It is very advisable to see that there is as little unproductive load as possible, for the consumer pays at the switchboard and realizes at the machine. In making the choice between central-station and other power, it is the engineer's business to analyze the conditions and to determine where the economy of one form of power ends and that of another begins.

LABOR AND LABOR QUESTIONS IN THE BOILER ROOM

Returning to the boiler room, and to the question of labor and labor conditions: is not the boiler room sometimes thought of as a black, dirty hole, where any kind of labor will do, and where one cannot expect to find intelligence equal to that found, and necessary, in the factory and office? Boilers, fuel, and water are provided; a fireman is employed, a shovel is put into his hands, and he is warned to keep the steam pressure up to a certain point. A new shipment of coal is dumped upon the firing floor. The fireman wades in it or stumbles over it, and gets rid of the overflow by the quickest route—the furnace. To make the work easier he shovels large quantities at long intervals. The damper is not rigged so that he can use it. He checks the rising steam by opening the fire door or by filling up with cold water. The boiler setting is full of leaks, and much of his labor and of the coal he fires is wasted in the useless heating of air. He has no means of knowing what draft he has, or what draft he needs. He does not know how hot his fire should be. He cannot know how much water he is evaporating to useful steam, or how much is lost through leaky valves and through condensation in bare pipes. He does not know how much water he is evaporating per pound of coal fired, or per B.t.u. bought and paid for; or how much more he could evaporate with the same, and with possibly less effort and cost. He learns that he has to fire more coal when his boilers are dirty; but he has no reserve units, and he knows that reporting a dirty boiler means losing his Sunday rest. He knows that he has to clean his fires occasionally; but since he is given no protection from the heat when cleaning, he tries to leave this job to the next shift; or else he burns his fire down to such a point that his boiler is practically off the line for half an hour. When the end of his shift comes at last, he draws a bucket of water from the injector overflow or from the water column, and retires behind the boilers where with the aid of a piece of soap and a doubtful towel he dislodges some of the grime from his countenance. He takes his street clothes from a nail, or from a makeshift wooden locker; and hopping first on one foot, then on the other, or sitting on a box or capsized bucket, he—dresses.

This is one type of boiler room, and where it is found, there will be found similar conditions in the factory. Here, indeed, is a field for the advisory engineer. Here is opportunity not only to save money by reducing costs, but to save money for the owner by improving the living conditions and the general satisfaction of the employee.

At the other extreme is the boiler room in which a high class of skilled labor is employed, in which careful records are kept, in which the cost of operation is a matter of study, and in which the welfare of the operating force is given thought. Even in a boiler room of this class the advisory engineer is of service. He can check the figures of the recorder; he can give information on a number of pertinent subjects with which the regular attendants have neither time nor opportunity to familiarize themselves. He can possibly see and call attention to sources of loss, the existence of which the regular force has perhaps overlooked. He can help in bringing the power-plant force into closer and better touch with the office, or with the superintendent. He can at the same time be an aid to that often sorely tried individual, the superintendent, who in many plants is held responsible by the executive office for every factory detail.

Living conditions in the boiler room are very much more important than many think them to be. At best a boiler room is a hot place, and at some seasons of the year, very hot. The chemistry and the physics of the power plant are often more intricate and potent than the chemistry and physics of the factory. It is certain that in the matters of personnel, equipment, and welfare our power-plant forces are as deserving of care as are our office and factory forces. On the humane view of this statement there is no argument. Industrially speaking, everything that can be reasonably done to improve power-plant conditions will earn a handsome return.

An Oxidization Process for Iron and Steel

THE deposition on iron and steel articles of an artificial layer of oxide, for protective or decorative purposes, is an old-established practice, and numerous methods therefor have been put forward from time to time. One of the latest processes is that invented by Dr. Alfred Mai, of Munich, Germany. Known as the Chemag process, it consists essentially in immersing the articles, for periods varying from 5 to 30 min. in an alkaline bath heated to a temperature ranging from 120 to 200 deg. cent., when a uniform, tightly adherent film of oxide is deposited on the surface. The color of the oxide layer may be varied by altering the concentration of the bath. In addition to a large proportion of caustic soda, the bath contains slaked lime, together with a suitable oxidizing agent, which may be a bichromate, permanganate, nitrate, peroxide, chlorate, or nitrite, or an organic oxidizing substance. An attractive feature of the process is that the activity of the bath may be continuously maintained by further additions of slaked lime. The temperature of the bath is not high enough to interfere with the mechanical properties of the steel articles. Upon removal from the bath, the objects are well washed with water, dried, and rubbed with oil to polish them.—*Engineering*, February 11, 1927, p. 163.

A Laboratory Study of Slag Erosion[1]

Progress Report of A.S.M.E. Special Research Committee on Boiler-Furnace Refractories

By SAMUEL J. McDOWELL,[2] COLUMBUS, OHIO

AN INVESTIGATION of boiler-house refractories is being carried on in a coöperative way by the Special Research Committee on Boiler Furnace Refractories of The American Society of Mechanical Engineers, the Fuel Division of the Bureau of Mines, and the Columbus Branch of the Bureau of Standards. It is the laboratory phase of this work being carried out at Columbus on which I shall touch today. The work was started while the Columbus Station was under the Bureau of Mines and was admirably outlined by Mr. G. A. Bole who was superintendent. Since July 1 the station has been known as the Columbus Branch of the Bureau of Standards, and the work has been continued with the fullest coöperation existing between the field and laboratory phases.

The work in the laboratory started about a year ago, and two men are employed on it. One is a ceramic engineer employed by the bureau, the other a mineralogist employed by the Special Research Committee. These men have at various times gone out into the field to obtain first-hand information, and the laboratory phase has kept in the closest touch with the field work so that the practical side might be stressed.

Object of the Investigation

The object of the laboratory work was an endeavor to throw light on the very interesting and complicated phenomena known as slagging, the ultimate object being an endeavor to develop laboratory tests which would properly evaluate the resistance of a refractory to a certain slag. It was also hoped, of course, that the work might point to some method of alleviation.

The tests which have been devised and used up to the present time have all been more or less empirical in their nature, and none have found universal application.

One of the early attempts consisted in making cup-shaped depressions in bricks and filling these cups with various slags. The bricks were then given a definite heat treatment, after which they were cut in two and the penetration noted. It was found that this test showed little more than porosity, as the porous bricks absorbed the slag more than the tight-burned ones, regardless of the other considerations.

Other tests have been used where bricks were heated in a furnace and made a target for various slags which were introduced in the gases. This carried the objection that the entire brick was heated and that the effect seemed to be more that of heat than slag action.

The early work of Bleininger and Brown and later work of Wilson and Schroeder consisted of immersing a refractory stick into a slag bath. One objection to this is that the slag attacks the container and changes composition.

Howe, Hewitt, and others have done some interesting work on the deformation of slag-clay mixtures, but conclude that the method has a limited applicability. Other tests have been devised which allow the molten slag to flow over the face of the brick—and such tests are being used in various forms, but there is little agreement as to the interpretation of results obtained.

The whole question of a suitable slag test has reached such an uncertain state that the American Society for Testing Materials has abandoned its tentative test, which was the cup test mentioned, and now has no specifications whatever, although it recognizes slagging as a major problem.

The reason why proper tests have not been devised is that the fundamental information has not been available upon which to build. Just what happens during the slagging process is not obvious, and only as more light can be thrown upon it can progress be made. It therefore seemed advisable to study the matter of slagging with every available laboratory tool to gain the necessary background, from which it is hoped eventually to develop a test which will simulate service conditions to such an extent that information obtained in the laboratory will check up with plant conditions.

Procedure

There are several ways in which the problem might be attacked. These may be briefly summed up as follows:

1 A thorough study of the thermochemistry involved and the development of equilibrium diagrams covering the various phases present. This is the type of work now being so ably done by the Geophysical Laboratory in Washington. This is an enormous undertaking due to the large number of components present, and we are hardly equipped to undertake it.

2 A continued search by the cut-and-try method for an experimental test which would fill the requirements, taking advantage of the previous mistakes of others. This method without background would not be likely to produce any more results than it has in the past.

3 A systematic study of the most important slag refractory systems, including a microscopic determination of the crystalline materials present and their relation to both glass and refractory, followed by an endeavor to duplicate these results in the laboratory. This procedure, which is really a compromise of the first two, was chosen.

Through the coöperation with the field investigation, samples of brick were sent to the laboratory after their life in service had been studied. Some special mixtures were also made up and fired either in the laboratory or under its control. They were then tested in service and sent in for examination. Most of the tests were made in a boiler using Illinois coal, although slag samples were also sent in from furnaces where two different Pittsburgh coals were used under different conditions.

A microscopic examination of an ordinary slagged brick which has been slowly cooled, as we go back from the heated surface shows (1) the slag itself, presumably in the same condition as it was deposited from the gases in the boiler. This consists largely of iron in the form of magnetite or hematite, glass, a lime-soda feldspar, and some mullite. With Illinois coal ash and an ordinary clay refractory, the slag is about 1/8 in. thick. This gradually blends into (2) the glassy interface. This in reality contains much more crystalline material than it does glass. Here, near the slag, are found grog grains partially dissolved or about to be washed out by the slag. There is considerable mullite in large-sized crystals, some of which seem to have grown from small crystals in the clay refractory to large ones in the slag. There is also some mullite which has actually precipitated from the slag itself. Magnetite and the feldspars are present in minor amounts. The thickness of this material is usually about 1/4 to 3/8 in. and grades into (3) the unaltered refractory. This usually shows little crystal structure for a fireclay brick, beyond some grains of quartz and tiny mullite needles in the ground mass.

It will be seen that the action of the slag on the refractory with the formation of these various crystal phases may offer an excellent opportunity for spalling to take place. There is a considerable volume change as some of these crystals are formed, and enormous strains may be set up by a change of only a few degrees of temperature. This has been found to check up with service conditions, and many of the refractories showed cracks developing in or just behind this so-called "glassy" interface as they were removed from the walls, although the fact that the slag is molten at high temperatures tends to make spalling less likely until lower temperatures are reached.

The other usual laboratory tests were made on the refractories. These included load and spalling tests, porosity, specific gravity, deformation, etc., and an effort was made to correlate them.

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[1] Published by permission of the Director of the Bureau of Standards.

[2] Superintendent, Ceramic Experiment Station, Bureau of Standards.

Presented before the American Refractories Institute, Pittsburgh, Pa., October 21, 1926.

Chemical analyses of the coal ash, slag, etc., were also available from the Fuel Division of the Bureau of Mines.

With these findings as a background, it was decided to start work on the development of a furnace which, it was hoped, would simulate service conditions to such an extent that the same mineralogical conditions could be produced as were to be found in boiler practice. It would then be possible to control such variables as:

1 Composition of the slag
2 Amount of slag in gases
3 Velocity of gases
4 Temperature
5 Furnace atmosphere
6 Duration of test.

These variables could then be tested one at a time and their effect noted.

To date, two types of furnace construction have been tried out and another is now being completed. In the first two types the furnace was long and narrow, and the test bricks were placed in the side walls with the burner in one end. In the latest type the walls are permanent, with the bricks to be tested in the arch. In each case a synthetic Illinois coal ash and powdered Illinois coal were introduced in closely controlled amounts into the air-gas stream, and the flame bathed the surface of the bricks. The powdered coal was used so that it would burn at the surface of the brick and produce local reduction, as would be the case in a boiler. In the later type of furnace there is also a secondary burner impinging on a bed of refractory material in the bottom of the furnace. This heat reflects on the arch, and it is thought it will thus be possible to have the surface of the brick hotter than the gases, as is true in a boiler of the chain-grate type.

The limits of some of the variables in this work have been roughly fixed for our conditions. With the use of any temperature higher than 2700 deg. fahr. in the furnace, the refractory seems to be affected more from the heat itself than the slag. One-half pound of coal and slag per hour has been used rather successfully with a neutral furnace atmosphere, although it will be necessary to study the effects in a much more thorough manner after the design of furnace has been finally decided upon. Little has been learned as yet of the other variables.

Microscopic examination has paralleled this furnace development and has shown that there is some similarity between the results obtained and the slag action in service. In one of the tests a water-cooled pipe was run up the rear wall of the furnace and temperatures obtained which varied from 2700 deg. fahr. in front to 2200 deg. fahr. at the outlet into the flue. A microscopic examination of the slag at these various temperatures and also field samples received, indicate that a fair idea of the temperature to which any coal-ash slag has been subjected may be obtained by the microscope. This is due to the apparent change of the plagioclase feldspar from those high in soda such as oligoclase and andesine at lower temperatures through labradorite and bytownite to almost pure anorthite at temperatures near 2700 deg. fahr. and seems to be true whether much or little is present. This is presumably due to the volatilization of soda, and is being further studied as to the effect of other variables. If this is shown by later work to be a function of temperature alone, it will point to very close relation between operating boiler temperatures and slag composition.

FUTURE WORK

At the present time the development of the furnace is being continued not so much as a test, although it is hoped this will come later, but as a method of controlling the variable factors. Work is also being started on that portion of the iron-calcium-alumina-silica system in which the usual crystal phases found in slag work fall, as it is felt necessary to obtain this piece of fundamental information before additional progress can be made. The work on the slagged refractories sent in from the field is being kept up to date and the microscopic phase stressed, as it is believed that this tool will throw the most light on this subject.

Later in the investigation when a furnace has been developed which will duplicate service conditions and the effect of the variables is known, and working in connection with the committee appointed by the Refractories Institute, we hope to be in a position to determine the effect of such things as process of manufacture, alumina-to-silica ratio, size of grain, temperature of firing, etc., of the refractory, and later plan to prove our laboratory findings with the installation of panels of brick in commercial boilers.

The Internal-Combustion Boiler and the Locomotive

BY THE internal-combustion boiler is meant here the Brunler boiler, described in MECHANICAL ENGINEERING, vol. 47, no. 5, May, 1925, p. 358.

The flame temperature at the boiler outlet is approximately 1800 to 2000 deg. cent. Since carbon monoxide burns to carbon dioxide at a temperature above 800 deg. cent., it is evident that at the high flame temperature of about 2000 deg. cent. all the carbon monoxide is converted into carbon dioxide. The steam-gas mixture, which has been frequently analyzed, has never been found to contain carbon monoxide. This shows that fuel can be burnt more completely in water than in the open. The combustion under pressure brings the molecules of the fuel into better contact with the oxygen of the combustion air; therefore, under pressure and in water a perfect combustion can be obtained. Due to the very high flame temperature, the water surrounding the former evaporates instantly. It is evident that after a few minutes the required steam pressure can be obtained. As a rule, a boiler pressure of 170 lb. per sq. in. is reached in practice within six minutes after the flame is submerged in the water. The gases produced during combustion consist of nitrogen, carbon dioxide, and slight traces of oxygen (about 0.05 to 0.03 kg. per kg. of oil burnt), and are mixed with the steam, forming a steam-gas mixture which consists of the same gases as those produced in gas and oil engines except that in these engines the proportion of steam in the combustion gases is much lower. As the specific heat of the steam-gas mixture is low and the mixture possesses extremely high powers of expansion, it follows that the maximum efficiency is obtainable from a highly superheated steam-gas mixture. In actual practice, the steam engine which worked with the steam-gas mixture at 170 lb. per sq. in. pressure and 680 deg. fahr. superheat required 11 lb. of steam gas per hp-hr.

The author then discussed various aspects of the air supply, comparing the economies of air compression with those of the internal-combustion engine, claiming that nearly as good results, considering fuel and air factors together, can be obtained as with the best Diesel engines, at the same time realizing the special operating convenience of the steam engine as applied to locomotive traction. He also included in his discussion a study of superheating aspects.

No drop in boiler efficiency due to incrustation can occur because incrustation never takes place, and the boiler efficiency is the same after a year's working as on the first day. Hard water can be used without any difficulty, and the minerals contained in the water settle down at the bottom of the steam generator, forming a sludge that can be blown off from time to time. The boiler efficiencies realized startle every engineer who learns of them. An efficiency of 99 per cent is guaranteed, and there is no difficulty at all in obtaining it.

Besides being able to reduce the fuel consumption by 50 per cent and retaining the reciprocating steam engine, a good many further advantages are obtained in using submerged flames for generating steam. There is no smoke or soot, no sparks to set fire to crops, forests, or prairies, no difficulty of storing fuel, even for a very long distance, and no boiler repairs due to wearing out of tubes or burning out of fireboxes. Also there is no back pressure needed for forced draft, and no difficulty of working at very high steam pressures. As the weight of the submerged-flame boiler is much less than that of present-day boilers, excessive axle loads can therefore easily be avoided. (Paper read by O. Brunler at a meeting of the Institution of Locomotive Engineers, Jan. 14, 1927, abstracted through *The Railway Engineer*, vol. 48, no. 556, Mar., 1927, p. 97, *d*)

Modern Fire Fighting in Oil Refineries

Causes of Fires in Tanks or Stills in Refineries and Methods and Procedures for Their Prevention—Foam Systems and Data Relating to Their Design

By FRANK A. EPPS,[1] NEW YORK, N. Y.

THE oil refiner has a special fire-fighting problem of his own. He should know how to meet the emergencies that arise in combating oil fires. If he is a wise refiner he will be fore-armed, and prepared to meet unusual fire situations.

Possibly no other word more aptly expresses the fire-fighting problem in oil refineries than "Preparedness." A great interest has developed in this subject in the oil industry. Practically all of the trade associations in one form or another are carrying on among their memberships an organized method of controlling and preventing oil fires.

Today modern fire fighting in oil refineries begins before the fire occurs. Most of the larger oil companies and many of the smaller ones maintain continual fire inspection and prevention service. As practically all of the causes of oil fires are well understood, their prevention is simply a process of applying known measures and using recognized safe practices.

The instances are rare when fire attacks oil-storage and handling equipment of modern design. Most oil fires are directly traceable to the use of construction which today is known to be hazardous. For plants built in accordance with recognized good practice, the fire frequency is exceedingly low. For plants that have in addition suitable appliances for handling oil fires, a trained fire brigade, and good plant maintenance, the fire risk becomes equal to the preferred class of industrial risk.

About two-thirds of the total fire loss sustained by oil properties consists of the destruction of oil tanks and their contents. Tank protection, therefore, is the principal item toward which the oil refiner must direct his attention in order to safeguard his plant. Lightning is the cause of approximately 55 per cent of all tank fires. Ignition resulting from exposure to fires that have originated in other structures is the direct cause of 33 per cent of the tank fires, and the remaining 12 per cent are ignited in an unknown manner, careless operation and static electricity probably being the principal causes of fires in this classification. Of the tanks ignited by lightning, it is of interest to note that approximately 93 per cent of them are not gas-tight. Most of them are equipped with wooden roofs. A detailed analysis of the fire records of the all-steel gas-tight tanks which were ignited during the period 1915–1925 gives evidence of unprotected vent openings. The fire records also indicate that tanks of this construction most frequently go through extremely severe conditions of fire exposure without ignition. It is evident, therefore, that the installation of all-steel gas-tight tanks, plus their proper maintenance, practically eliminates the bulk of the fire danger.

Of all the tanks lost by fire in the period 1915–1925, 58 per cent contained crude petroleum, 20 per cent gasoline, 17 per cent kerosene and like oils, 3 per cent fuel oil, and 2 per cent miscellaneous oils. Thus the majority of oil tanks that burn contain crude oil. This is to be expected, because of the fact that fire danger and wooden tank roofs are synonymous, and such tanks are used principally for crude oil.

The annual frequency of fires per 1000 tanks during the ten-year period 1915–1925 was as follows:

Contents	Wooden-roofed tanks	Steel-roofed tanks
Gasoline	17.9	0.26
Kerosene	15.2	0.28
Crudes	4.15	0.64
Fuel oil	1.44	0.45

The relative safety of the steel-roofed tank is evident.

In order to prevent fire in tanks, the following are the principal considerations to be borne in mind:

[1] General Engineering Department, Tide Water Oil Company.

Contributed by the Petroleum Division and presented at the Annual Meeting, New York, December 6 to 9, 1926, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

FIRE-PREVENTIVE TANK CONSTRUCTION

Tanks should be set upon firm foundations, reinforced-concrete slabs being preferable for all permanent installations.

Tanks should be constructed of open-hearth steel equivalent to Structural Grade "A" as specified by the American Society for Testing Materials. The absence of a specification on steel permits the manufacturer to supply almost anything, and this has, in certain cases, resulted in failures in the tank shells shortly after construction. Vertical tanks should be designed for a factor of safety of not less than 2.5, based on the tank being filled with water. Top angles should be located inside rather than outside in order to permit calking of the top-angle joints. Roof plates should be not less than $^3/_{16}$ in. in thickness as it is impossible to secure tightly calked riveted joints with thinner metal. In this connection it should be noted, however, that a number of tank builders are now welding the roof seams, and with this form of construction it is possible to obtain a tight roof with thinner metal.

ROOF FITTINGS

Gage hatches should close by weight only and should be so designed that they will lift and vent the tank prior to roof failure, should pressure be built up in the tank, perhaps due to a fire in an adjoining structure. Such hatches, however, should be gas-tight when they are in closed position. All other openings in the tank roof, such as explosion hatches, manholes, etc., should be securely gas-tight. Venting connections for tanks containing crude oil, gasoline, and other volatiles should preferably be of the sealed type and should have ample capacity to relieve any vacuum which can be developed within the tank under the most abnormal conditions of pumping out and simultaneous cooling from a shower on a hot day. Such vents should be equipped with suitable flame arresters, and in this connection it should be noted that metal screens arrest flame only by reason of their ability to conduct the heat away very rapidly to adjacent solid-metal parts, thereby preventing the formation of ignition temperatures on the other side of the wire screening. If the distance from the central part of the wire screen to solid metal is too great, a single thickness of screen will not serve, but a double or triple thickness is required. Beyond certain dimensions even a triple thickness of wire screen may be unsatisfactory. The actual limitation of wire-screen flame arresters has not been fully determined. The Underwriters Laboratories of Chicago, Illinois, conducted an extensive investigation in 1919 in conjunction with the E. I. du Pont de Nemours Company. A number of oil companies have performed some experimental work in this connection, but the investigation work to date is incomplete. At its meeting this week in Tulsa, the American Petroleum Institute will consider the advisability of devoting an appropriation for further research in this direction.

All remaining holes through the roof plates should be effectively closed; for example, if a swing-pipe connection is employed, a stuffing box should be provided where the cable passes through the roof.

WOODEN-ROOFED TANKS

Where wooden-roofed tanks are employed, very careful consideration should be given to the advisability of replacing them with steel roofs. Where this cannot be done, the wooden roof should be placed and kept in excellent repair, and an overhead system or network of grounded conductors should be supplied and connected to grounded metal towers located at a suitable distance away from the tank or tanks protected. This system of lightning protection is in use today in California for oil-reservoir protection and has been described in detail in the trade publications. The overhead network of wires will relieve the roof of the induced-charge effect which occurs during a thunderstorm and is responsible for the ignition of many wooden-roofed tanks. The grounded steel towers, if

properly located, will receive and safely handle direct hits which might otherwise strike the tank.

Another form of lightning protection for wooden-roofed tanks provides heat insulation for the wood deck by which the tank is made gas-tight at the same time. In addition to this a network of grounded conductors is stretched over the top of the tank and supported by steel posts affixed to the tank shell. Unquestionably this "Faraday Cage" gives excellent protection from induced charges, and also provides a fair degree of protection against direct hits.

Fire Walls

Fire walls should always be provided around crude tanks and should be:

a Of a capacity equal to that of the tank surrounded, unless adequate drainage to a sump of like capacity is provided

b Located not nearer to the shell of any of the enclosed tanks than the diameter of the largest tank enclosed, and in any case not less than 50 ft.

c Provided with a suitable coping projecting inward to turn back boil-overs.

The construction and function of the coping referred to was described very completely in a paper presented by Mr. H. H. Hall of the Standard Oil Company of California before the American Society of Civil Engineers last year.

For other than crude tanks, fire walls are so seldom required during actual fires that their construction is unwarranted except under conditions of an unusual nature wherein the exposure of large values justifies extraordinary measures.

Grounding

A ground connection of some kind is necessary. However the earth under the bottom of most tanks is usually moist and is a sufficient ground even in exceptionally dry regions. In addition, the pipe lines connected to the tanks are usually embedded in moist earth at a point not far from the tanks. However, for tanks resting on concrete slabs and connected to an above-ground system of piping, an electrical ground is essential. This also applies to tanks resting on cinders, wood, or other insulating foundations. Grounds are most frequently obtained by driving iron pipes to permanent moisture and connecting them by means of substantial copper cables to the shells in the tanks. The use of "Paragon" cones is also to be recommended. These are baskets or cones made of perforated sheet copper. It is customary to fill them with charcoal (which acts as a moisture retainer), and the filled baskets are deposited in holes made by a fence-post borer in the vicinity of the tanks, the holes being extended to the depth of permanent moisture. Heavy copper cables connect the tank shells to the buried copper baskets.

Fire Protection

As before noted, the probability of fire in all-steel gas-tight tanks is very remote, and except in cases where large values are involved or where other considerations warrant a considerable investment in fire-protection equipment, it should not be necessary to make any special provision for fire protection. Proper tank construction and proper maintenance provide in themselves very complete protection.

However, in large plants, where fires originating in other structures must be handled, it is customary to provide both steam and foam protection for the tankage because of the large values involved. The adequacy of steam installations as they are designed and installed today is very questionable, as was developed in a paper read by Mr. G. O. Wilson in January, 1926, before the American Petroleum Institute's convention at Los Angeles.

The only effective fire-extinguishing agent for all tank fires is foam. Where properly installed and maintained, such fire-extinguishing systems will always give a good account of themselves. The use of foam in this country is comparatively recent, the entire development being only about 12 years old. Nevertheless, today there are very few modern refineries which do not have foam systems. Almost without exception, where they have been installed in accordance with the standards of design which are outlined in the following pages, they have operated successfully and have saved much property that would have otherwise been lost.

Several other types of tank-fire extinguishing equipments have been and are being developed which utilize water sprays, carbon tetrachloride, and carbon dioxide. As applied to oil tanks, these equipments are still in the experimental stage and have only a record of test fires to their credit.

Operation

Under no circumstances should an excavation be made under a tank in order to repair a leak in the bottom, unless the tank has been entirely emptied. Failure to observe this precaution has resulted in failure of the bottom plate and loss of contents of tank, not to mention narrow escape from drowning on the part of the men around such excavations.

Gage poles should be fitted with brass hinges and shoes instead of iron so as to eliminate possibility of mechanical sparks. Gaging tapes for the same reason should be fitted with brass plumb bobs. The gager should be instructed regarding the necessity of keeping all hatches closed, and violation of this rule should be sufficient reason for discharge.

Before making repairs on any tank, a gas-free certificate should be obtained from the laboratory. The use of electric extension lights should be prohibited in tanks that have previously contained volatiles, unless the most rigid procedure has been followed in cleaning and "gas-freeing" the tank.

Inspection and Maintenance

In the relatively few cases of ignition of all-steel gas-tight tanks, it has been observed that such ignition resulted directly because of some defect in equipment which rendered the tank sub-standard at the time of ignition. This is a fact of prime importance, emphasizing as it does the necessity for continual tank maintenance. Every oil company should, if this is not already its practice, institute at once careful and periodical inspection of such equipment. Records of these inspections should be kept, and the defects found should be promptly remedied.

The National Petroleum Association has already instituted among its membership a "Fire Marshals' Association." The member companies have appointed in their refineries a group of men known as fire marshals who make periodic inspection of all tanks and equipment. These men report to some one in executive authority in their respective plants. Inspections are made and reports are prepared on standard forms. While on the subject of inspection of tanks, it is of interest to note that the N.P.A. fire marshals likewise inspect the fire-protection equipment and all structures such as buildings, stills, and loading racks.

Next to oil tanks, the greatest fire risk in oil refineries is to be found in the distillation equipment. Fire prevention around such equipment can be summed up in a single phrase: Careful operation and first-class upkeep.

Most frequently fires occurring in the distillation process are caused by small oil or vapor leaks. They are usually put out with hand extinguishers, steam jets, water hose, or by pumping out the still with negligible loss. Occasionally, however, something lets go, a still bottom splits, a high-pressure drum explodes, or an oil line breaks, and a big fire is under way. In order to handle fires of this type, the distillation unit should be designed and installed with the following three points in view:

1 Provision of facilities for the rapid removal of the oil in the burning still and in nearby stills

2 Provision of facilities for confining the spread of the fire

3 Provision of adequate fire-extinguishing equipment.

Dealing with these in the order named, it is evident that one of the simplest and most effective ways of handling a serious still fire is to quickly pump out the burning still and those which are menaced. Therefore the importance as a fire-protection measure of having large pumps for this purpose and large pumping-out lines is apparent. It is essential, however, that all valves in the pumping-out line shall be equipped with remote controls, so that they can be operated safely and surely—usually from in back of the condensers. Serious consequences may result if during the excitement the still is pumped out without having top steam turned on. It is quite probable that failure to observe this point has been responsible for many of the still explosions and the resultant loss of

life which have occurred during such fires. Since the steam line is so important, its valve control should be just as accessible as the pumping-out valve control, and its installation should be reasonably secure against injury.

In order to limit fire spread, it is important to provide, as far as practical, fire walls around every battery of stills. Frequently the near walls supporting the condenser boxes may be used as part of this surrounding fire wall. It is further desirable to break up the fire areas in and around the units of any battery, so that a flood of hot oil pouring from a break will endanger as few adjoining stills as possible. Catch basins and sewers should be connected to the areas so enclosed, and such connections should drain to remotely located separator ponds.

It frequently happens that small fires assume serious proportions because oil and vapor lines are improperly supported. The collapse of their supporting members and consequent breakage of lines or fittings permits the contents of these lines to drain stills and add fuel to the blaze. It is of prime importance, therefore, that crude charging lines, flow lines, vapor and reflux lines, fractionating towers, and such equipment be supported by structural members properly insulated. Poured concrete made of limestone aggregate and having a thickness of from three to four inches is most suitable for this service. Complete particulars regarding the degree of fire protection afforded by different types of heat insulation may be obtained from Fire Tests of Building Columns, published by the Underwriters Laboratories of Chicago in 1919.

Fire-protection equipment around stills usually consists of first-aid fire-extinguishing devices, as $2^1/_2$-gal. foam extinguishers and 40-gal. foam chemical engines, steam hose fitted with long extension nozzles, water hydrants and hose, and foam hydrants and hose.

FOAM SYSTEMS—DRY-CHEMICAL TYPE

Foam systems are of two general types, namely, the dry-chemical portable type and the stored-liquid stationary type. The former is a very recent development and its limitations have not yet been fully determined. In general, this type of installation seems to fill the need for foam equipment intermediate both in capacity and in cost between the portable wheeled foam fire extinguishers and the stored-liquid stationary type of installation.

The dry-chemical equipment consists essentially of a so-called "foam generator" which weighs about 110 lb. and requires from 60 to 100 lb. of water pressure for its successful operation. A line of $2^1/_2$-in. hose is extended from a water hydrant to the generator, and 50 to 150 ft. of hose of the same size connects the discharge of the generator to the nozzle. The generator itself is essentially a water ejector, which is mounted on a portable frame and equipped with a funnel or hopper. The vacuum surrounding the constricted water stream in the ejector draws the dry chemical contained in the hopper into the water. The component chemicals in the presence of water immediately dissolve and react, so that a stream of the resulting product—foam—issues from the nozzle. The dry-chemical powder consists of sodium bicarbonate, ground aluminum sulphate, powdered foaming extract, and a small percentage of inert clay, all ground to a fine mesh, thoroughly mixed and packed in 40-lb. cans, hermetically sealed. These cans are supplied with quickly detachable covers, and in case of fire the contents are poured into the hopper of the generator at the rate of about two cans per minute.

The effectiveness of this type of equipment is measured by the following:

1 An adequate supply of water at the required pressure
2 The quantity of dry chemical in storage. Obviously this device can supply a foam stream as long as the water supply and the supply of dry chemicals last
3 The auxiliary connections which are available to assist in discharging the entire output directly on the seat of the fire.

In the author's opinion, the limit for one generator under good conditions is about 500–700 sq. ft. of burning oil surface. On a fire much larger than this, the foam will probably be consumed as rapidly as it is applied. The minimum quantity of dry powder in storage should be sufficient to keep all generators in operation for a period of about one hour.

FOAM SYSTEMS—STORED-LIQUID TYPE

This type of foam installation provides storage containers or tanks for two chemical solutions, "A" and "B." The remaining part of the installation consists of a pump, pipe lines, and devices for mixing the solutions and applying the foam to the fire. In case of fire, the two foam chemical solutions are pumped separately in equal volumes through a twin system of pipe lines to specially designed mixing chambers mounted on the oil tanks, or to portable devices which are provided for emergencies.

The two foam chemical solutions "A" and "B" are made up in the following proportions:

	Percentage by weight	Contents of one gallon of solution
Solution "A"		
Aluminum sulphate	13	1.163 lb.
Water	87	0.935 gal.
Solution "B"		
Sodium bicarbonate	8	0.708 lb.
Liquid foaming extract	3	0.265 lb.
Water	89	0.946 gal.

When these two solutions are mixed, the following chemical reaction takes place: $6NaHCO_3 + Al_2(SO_4)_3 = 3Na_2SO_4 + 6CO_2 + 2Al(OH)_3$. It will be noted that the liquid foaming extract plays no part in the chemical reaction. When the sodium bicarbonate and aluminum sulphate combine, there is a rapid effervescence of the mixed liquids resulting from the formation of the carbon dioxide gas. Simultaneously, the formation of gelatinous aluminum hydrate reduces the surface tension of the liquid to the point that bubbles are quickly formed. The presence of the foam stabilizer makes these bubbles extremely tough, durable, and tenacious. The two solutions are of such concentration that when equal quantities of each are mixed, they produce approximately eight to ten times their combined volume in foam. This foam has the property of floating on liquid surfaces, adhering to walls, ceilings, etc., and in fact coating any surface which can burn. Once such a surface is so coated, the fire is effectively extinguished and cannot reignite until the foam breaks down, which it does very slowly.

Actual tank fires have demonstrated that from one to two gallons of each chemical solution are required per square foot of burning oil surface before the fire is extinguished. It is customary to provide a factor of safety in the amount of chemicals which are carried on hand in liquid storage, as it is practically impossible to mix the dry chemicals rapidly enough during a fire to replenish the supply. Obviously, the several factors are as follows:

1 The area of the largest tank
2 The area of other tanks in the immediate vicinity of the largest
3 The total number of tanks to be protected
4 Allowances for favorable conditions such as incombustible roof, oil of low volatility, etc.

These factors have been combined in the following empirical formula:

$$S = (5A + 3B + 2C + D) \times [1 + 0.02(N - 5)] \times (1 - R)$$

where

S = volume (U. S. gal.) of each chemical solution to be provided
A = area (sq. ft.) of oil surface of the tank having the largest exposed area[2]
B = area (sq. ft.) of oil surface of all tanks (not including oil tank "A") within the exposed area[2] of tank "A" and lying wholly or partially within a distance of one tank diameter[3] from tank "A"
C = area (sq. ft.) of oil surface of all tanks (not including oil tanks "A" and "B") within the exposed area[2] of oil tank "A" and lying wholly or partially within a distance of two tank diameters[3] from oil tank "A"

[2] Exposed area is the area represented by that quadrant of a circle (whose center is the center of that tank and whose radius is equal to $3^1/_2$ times the diameter of that tank) which yields the largest amount of solutions when calculated in accordance with the foregoing formula.

[3] Distance expressed in diameter of oil tank "A" and measured from shell (not center) of oil tank "A."

D = area (sq. ft.) of oil surface of all tanks (not including oil tanks "A," "B" and "C") within the exposed area[2] of oil tank "A" and lying wholly or partially within a distance of *three* tank diameters[3] from oil tank "A"

N = ratio of total oil surface area of all protected tanks on premises to oil surface area of oil tank "A"

R = reduction in solution quantity depending upon conditions favorable to fire extinguishment such as low volatility of oil, incombustible roof members, etc. = 0 to 50 per cent.[4]

Solution "A" is good until used unless it becomes contaminated with oil. Solution "B" is subject to slow deterioration. The sodium bicarbonate in aqueous solution will gradually revert to normal carbonate as follows:

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

Loss of CO_2 reduces the volume of foam which the solutions should normally produce. Frequently the fire-extinguishing quality of the foam is likewise affected. When the loss in volume approximates 25 per cent, it is customary to consider the "B" solution to be in unsatisfactory condition, and steps are then taken to "revivify" it.

TABLE 1 FRICTION LOSS IN FEET OF HEAD PER FOOT OF PIPE

Diameter of pipe, in.	Required Gallons per Minute											
	1	3	5	7½	10	15	20	25	30	40	50	75
½	0.02	0.16	0.41	0.87	1.47	..	..	..	..	..	..	..
¾	..	0.04	0.11	0.22	0.38	0.8	1.36	..	..	..	..	..
1	..	..	0.03	0.07	0.12	0.25	0.42	0.64	0.89	1.52	..	..
1¼	..	..	..	0.02	0.03	0.06	0.11	0.17	0.24	0.40	0.60	1.29
1½	..	..	..	..	0.01	0.03	0.05	0.08	0.11	0.19	0.28	0.60
2	..	..	..	..	..	0.01	0.02	0.03	0.04	0.07	0.10	0.21
2½	..	..	..	..	..	..	..	..	0.01	0.02	0.03	0.07
3	..	..	..	..	..	..	..	..	..	0.01	0.02	0.03

TABLE 2 FRICTION LOSS IN FEET OF HEAD PER FOOT OF PIPE

Diameter of pipe, in.	Required Gallons per Minute												
	100	150	200	250	300	350	400	450	500	550	600	800	1000
1½	1.02	..	..	..	..	..	..	..	..	..	..	..	..
2	0.36	0.76	1.29	..	..	..	..	..	..	..	..	..	..
2½	0.12	0.26	0.43	0.65	0.92	1.22	1.56	..	..	..	..	..	..
3	0.05	0.11	0.18	0.27	0.38	0.50	0.65	0.80	0.98	1.17	1.37	..	..
4	0.01	0.03	0.04	0.07	0.09	0.12	0.16	0.20	0.24	0.29	0.34	0.57	0.88
6	..	..	..	0.01	0.014	0.018	0.022	0.027	0.034	0.04	0.05	0.08	0.12
8	..	..	..	..	..	..	..	..	..	0.01	0.012	0.02	0.03
10	..	..	..	..	..	..	..	..	..	..	..	..	0.01

Fortunately the above chemical reaction is reversible, and by adding an excess of CO_2 gas to the "B" solution under pressure, it is possible to restore the original efficiency at about one-tenth the cost of renewing the solution.

Occasionally the solutions become contaminated with traces of oil, and the quality of the foam is seriously affected. Under such circumstances, the solutions have to be renewed as no effective way of completely removing the oil has been devised.

It is customary to provide either two or four foam-solution tanks at each installation. It is safer to have the solutions stored in four tanks than in two, as repairs to one tank, renewals of solutions, etc., can be effected without putting the entire system out of commission. Tanks for the "A" solution should be lined with lead, as this solution readily attacks iron and steel.

When such an installation is erected in climates where freezing temperatures are encountered, the tanks should be housed, or encased with tile jackets. If the latter method is followed the jackets should be spaced sufficiently far from the tank shells to permit of the installation of steam coils in the annular space surrounding the tanks. Heating facilities in the housing or jacket should be sufficient to keep the temperature of the solutions above 60 deg. fahr. Heating coils installed within the tanks and in contact with the liquids are unsatisfactory, particularly in the "A" solution. It will be found that coils so installed give continual trouble.

Where large amounts of foam solutions are stored, it is customary to install a relatively small dissolving tank. The solutions can then be prepared in the small tank in batches and pumped into the large storage tanks.

The dissolving tank is usually sunk into the ground with its top just above grade. A grating is placed over it, so that barrels and drums containing the chemicals may be rolled thereon and emptied into the tank. Depending upon the size of the installation, the dissolving tank normally ranges in size from 500 to 2000 gal. capacity.

Positive-displacement pumps, preferably of the piston type, are generally selected. The pistons handling each solution, having equal displacement and operating at the same speed, displace equal volumes, thus metering equal amounts of chemicals and producing the best foam. Such pumps are usually steam driven, but power pumps driven by a prime mover are frequently employed. The capacity of the pump should be such that it will deliver one-twentieth of a gallon per minute of each of the two foam solutions for every square foot of area on the largest risk, viz., the area of the largest individual oil tank protected.

Steam-driven pumps of the twin duplex type are most frequently employed. It is important that the valves and ports of the pumps be large so that when operating at rated capacity the fluid velocity through them shall not exceed 200 ft. per min. Both ends should be fully bronze-fitted.

The pump selected should be capable of developing a pressure when operating at its rated speed which will deliver the required quantity of solutions to any part of the plant.

Tables 1 and 2 supply data on friction losses so that the designer can determine the size of pipe lines required, after having first determined the quantity of each solution which must be provided for each risk to be protected.

In general, standard-weight wrought-steel pipe and cast-iron fittings are employed throughout, except that steel or malleable-iron fittings are used in the vicinity of tanks or other risks wherein the severe stresses of explosions may be encountered, or where the heating and cooling effect of alternate application of fire and water may be experienced. Rising-stem gate valves are employed and are therefore self-indicating. Where valves are normally in contact with the "A" solution, a specially designed acid-resisting valve is used, otherwise brass or iron-body brass-fitted valves are used.

All pipe lines inside fire walls and near tanks should be laid at least six inches below ground. All underground pipes should be protected from corrosion by the application of hot asphalt or other bituminous preparation prior to placing the pipe. All valves should be located by conspicuous markers. Drains should be provided at low points in all field lines.

Control valves should be located outside of fire walls and not less than a tank's diameter away from the tank they control. In no case should such control valves be located nearer than 50 ft. to the tank protected.

Suction lines for each chemical solution should be protected from freezing by being placed in underground conduit or pipe trenches through which a steam-heating line passes.

In general, the connections at the pumps should be so arranged, first, that the solutions may be drawn from the solution tanks and discharged into the field lines; second, that the suction and discharge connections on the pumps can be reversed so as to suck from the field lines and return the solutions therein to the tanks; third, fresh-water connections should be made to the pump suctions, these connections being independent of the suction lines for the chemical solutions; fourth, the pump suctions should have connections to the dissolving tank so that the freshly mixed chemical solutions may be withdrawn therefrom and discharged into the solution tanks.

In order that the foam solutions may be effectively applied to a burning tank, it is desirable, first, to produce the foam as near the fire as possible; second, to have the chemical reaction completed before the foam reaches the fire, and, third, to subject the foam to as little rough usage as possible.

So-called mixing chambers are manufactured for this purpose and are devices that are adapted for permanent installations on vertical oil tanks, so that the foam may be generated in them

[4] For such tanks as have roofs of all-steel construction and/or contain high-flash-point oils (fuel, lubricating or gas oil, wax, paraffin, tar, etc.) on properties the nature of which assures that the class of the tank contents will remain unchanged, reduce the factors by 0 to 50 per cent, according to conditions, i.e., to the proportion of the aggregate area of tanks with roofs of all-steel construction or high-flash-point oils to the total area of all tanks. Where all tanks contain oil of low volatility, the maximum credit is 20 per cent. Where all tanks are of all-steel construction, the maximum credit is 30 per cent.

and discharged into the tanks over the top of the shell through an opening in the roof. It is important that the connection between the mixing chamber and the tank shall be very secure, but the connection to the tank roof must be very fragile (but gas-tight) so that if the roof is damaged by an explosion, the mixing chamber will be unharmed. Also, it is advisable for tanks containing volatile oils to have the mouth of the mixing chamber sealed so that the vapors will not condense in the mixing chambers and run back into the pipe lines.

In selecting mixing chambers for any tank, it is desirable to secure the manufacturer's recommendations both as to size and type of mixing chamber to be employed.

No foam installation is complete unless foam hydrants are provided and available for use at all locations where oil fires may occur. In general, they should be located not nearer than 50 ft. and not further away than 250 ft. from the risk which they are to protect.

Hose reels should be provided and located at strategic points around the plant. These portable reels should be equipped with twin lengths of rubber-covered, rubber-lined linen hose. The working length of hose on the reels usually varies from 100 to 300 ft., according to the spacing of the hydrants in the risk protected. The reels are housed in buildings designed for that purpose, and carry suitable mixing nozzles, spanner wrenches, gaskets, hydrant wrenches, etc.

In certain instances, especially in congested refineries, it may be advisable to have the hose coupled to the hydrant and stored in specially prepared hose racks.

The standard size of hose adopted for foam systems is $1^1/_2$-in. rubber covered and rubber lined. However, in large refineries, where there is a sufficient crew to handle heavier hose, $2^1/_2$-in. hose is frequently used. These lines are Siamesed together into a $3^1/_2$-in. mixing tube connected to a suitable play pipe. In general, not less than 30 lb. pressure and preferably 60 lb. should be available at the nozzle.

It is customary to assume that the $1^1/_2$-in. line will discharge 75 gal. per min. of each solution, whereas the $2^1/_2$-in. line will discharge about 250 gal. per min. of each solution. The mixing-nozzle sets referred to in the foregoing are of standard design and comprise the following equipment:

$1^1/_2$-in. units...
- 1 nozzle, $2^1/_2$ in. × 30 in.
- 1 nozzle tip, $1^1/_8$ in. smooth bore
- 1 mixing tube, $2^1/_2$ in. × 5 ft.
- 1 Siamese connection, $1^1/_2$ in. × $1^1/_2$ in. × $2^1/_2$ in.

$2^1/_2$-in. units...
- 1 nozzle, $3^1/_2$ in. × 14 in.
- 1 nozzle tip, $1^3/_4$ in. smooth bore
- 1 mixing tube $3^1/_2$ in. × 8 ft.
- 1 Siamese connection, $2^1/_2$ in. × $2^1/_2$ in. × $3^1/_2$ in.

All threads on nozzles, mixing tubes, and Siamese are straight iron-pipe hose threads.

There are many special applications of foam protection that have not been given space in this paper. The design of adequate foam protection for special risks is a subject in itself; however, the following are the principal items to be considered.

1 A *more than adequate* supply of foam solutions
2 Pipes and delivery facilities large enough to put properly mixed foam on the fire *rapidly*
3 Mechanical perfection of design of all parts—especially those handling the "A" solution
4 Adherence to tried methods and apparatus
5 Facilities for inspection and testing. Don't forget that the equipment may stand idle for years before it is called into service.

In conclusion, the fire record of the oil business is remarkably good, considering the nature of the products handled, their volume, and the far-reaching extent of the industry. Oil fires seldom occur, but when they do they may be readily segregated, controlled, and extinguished when good design and adequate fire equipment are employed.

The Boiler House in Oil Refineries

Factors of Importance in Refinery Heat-Balance Calculations—Method of Utilizing Every Heat Unit Generated in the Steam and of Conserving Those Now Wasted Through Exhaust—Savings Possible Through Adoption of Plan

BY H. A. ROSS,[1] NEW YORK, N. Y.

HEAT is one of the most important factors in the processing of petroleum products. The quantity and quality of the various derivatives, therefore, are dependent, first upon the quality of the heat produced; second, upon the quantity; and third, upon the intelligence with which it is produced and applied.

Obviously, then, the economical production and application of this important element must to a considerable degree determine the extent of refining costs, and this becomes of paramount importance in the economic refinery manufacturing structure.

The unusual complexities of processing petroleum in both large and small refineries require a heavy capital investment for heat equipment with which to manufacture the various products. These products range in gravity from the lightest volatiles to the heaviest tars, and each of these requires heat in a varying degree. They are all refined in accordance with extremely rigid standards, universally used throughout the industry. The majority of these standards are founded on or derived from a basis of temperature or heat formulas.

Probably 60 per cent of the fuel which a refinery consumes in its production of heat is used to generate steam. The steam is generated, of course, in the boiler house and its auxiliaries.

It is a well-known fact that waste of fuel in the production of industrial heat is universally prevalent today. Probably the oil refiner transgresses in this respect to no greater an extent than does any other manufacturer. When we consider, however, that a refinery is in continuous operation 24 hours a day or 8760 hours a year, we are impressed with the fact that its fuel cost and possibility of loss are considerably greater than those of a plant operating on a shorter hourly basis per day.

Assume that a refinery consumes 40 net tons of coal per 24 hours costing $3.50 per ton laid down. The daily fuel bill is then $140. If 50 per cent of this fuel is either a preventable or recoverable loss (and this statement is not overdrawn as will be shown later), we are confronted with a condition of serious economic import to any industry.

There are other factors just as important in this analysis, such, for example, as the manner in which the heat of the steam is applied, and when they are added to the initial cost of the fuel, additional preventable loss occurs. Add to this again the cost of labor to produce the heat, cost of maintenance, depreciation, interest, etc., and a loss of staggering proportions is encountered.

A large refinery boiler house may have a capacity of 12,000 b.hp. and operate 80 per cent of it at 150 per cent of rating with a combined efficiency of boilers and grates as high as 75 per cent. But in order to secure this, coal- and ash-handling equipment, modern boiler settings, automatic stokers, together with a varied assortment of instruments, will be required. In addition to this, accurate records and continuous systematic tests must be conducted by trained engineers in order that close check on operation may be

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[1] Steam Engineer with H. S. Bell, Consulting Petroleum Engineer. Mem. A.S.M.E.

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had. As a further condition of such high fuel efficiency the employment of specially trained firemen is necessary, and all operations of the entire power-plant organization must be controlled by men of unquestioned skill and training in this particular field.

For the purpose of contrast, consider the small refinery. In most cases it is controlled and operated by a one-man management in all of its departments, yet it manufactures products identical with those of the large one. The small refinery may consume only 20 tons of coal per day under the boilers at an average efficiency of not over 45 per cent. This small boiler house may not have over 350 or 400 b.hp. capacity. As a rule the boilers are of the horizontal-return tubular type, hand-fired. Auxiliary to them will be two duplex steam pumps for boiler-feed purposes and a feedwater heater of a sort. The coal- and ash-handling equipment is usually a wheel-barrow, and all other accessories such as recording meters, thermometers, and gages are seldom found.

The small refiner, therefore, does not have to contend with the operating difficulties of the large boiler house, and because of the many other problems demanding his attention, has more or less neglected his boiler house. This has penalized him by heavy loss at the coal pile: first, by improper boiler-house routine, and secondly, by misapplication of the heat produced to his processes.

Between the extremes of the large and small boiler houses may be found many others of varying capacities. But up to and including those of 1000 b.hp. they are, as a rule, generally equipped with hand-fired, horizontal-return tubular boilers.

If it is true as stated that the large boiler house may secure efficiencies of 75 per cent or higher from its steam-generating equipment and the small one only 45 per cent, it would appear that the small plant carries an initial 40 per cent fuel handicap. It is this big problem which first confronts the engineer in an economic survey of the small plant.

Factors of Importance in Refinery Heat-Balance Calculations

While considerable information has been collated by the larger plants, this in many instances is unreliable, and of little value as well, in comparative thermal calculations.

A refinery will estimate that it consumes 15 lb. of steam in processing a gallon of oil; another that it uses 12 lb. Both of them are producing similar products from the same base or source. Apparently one refinery then requires 20 or 30 per cent more steam than the other. Whereas if they were each to report their consumption on an equivalent heat basis it would be found that the discrepancies were not as great as they appear to be. It is true that the physical condition of a refinery and its boiler house is often a large factor, but the quality of the heat is equally as important.

There are other factors also of much importance in this connection when a refinery heat balance or analysis is attempted on the basis of steam production and consumption per unit of the material processed. These are:

1 The quality of the steam as represented by its temperature and percentage of saturation
2 The percentage of products re-run
3 The methods by which the steam is produced and distributed
4 The mechanical condition of the equipment in general.

Probably not over 40 per cent of the steam a boiler house produces in a refinery is required for mechanical equipment, the remainder being used for purely processing and heating purposes. This being the case, it is apparent that the greatest percentage is required for either the heat it contains or else its kinetic energy, or possibly both (this is particularly so in the distillation processes carried on in the stills). The internal energy or entropy in the steam may be ignored with safety in the small refinery, but it is felt that in large refineries with central boiler houses and long distribution lines carrying steam at extremely high velocities, due consideration should be given it.

If the above statements are true, each boiler house becomes a distinct problem separate and apart from every other one, for the reason that the operations conducted in the plant have a reactionary effect upon the steam-producing equipment. This is the underlying reason why some large refineries today are in the same condition as the small ones in so far as their production of heat in the boiler house is concerned.

The outstanding fault in the majority of refinery boiler houses both large and small is a shortage of steam and the inability of the power department at times to satisfy or supply the refinery demand. Times without number certain departments will be forced to cease operating in order that pressures may be maintained to operate others. This condition occurs so frequently as to become a matter of almost daily routine, and may upon occasions become sufficiently critical to temporarily, at least, shut down the entire plant. When such conditions do arise, a further increment must be added to the prevailing fuel and waste-heat loss.

Granted that a boiler house may not be of sufficient capacity, it is frequently found that intelligent application of sound engineering practice in it and the refinery will materially reduce the excessive drain upon its resources and automatically increase the capacity. In addition to this, and as a direct result of scientific management, the unit cost of the steam will be materially reduced. A survey conducted in a number of refineries during the past year has disclosed that without any expenditure of money whatever, $10.76 per hp. per year can be saved on a total installation of 14,400 b.hp. This saving of $154,000 can be secured by simply changing the old manner of firing the boilers, and no investment whatever is required. This survey also showed that only 70 per cent of this capacity or about 10,000 hp. was being actively employed and operated. Thus if the saving per hp. was estimated on the amount in actual service, the saving per unit would be $15.40.

Still more interesting is the fact that in several instances savings of from $18 to $24 per hp. per year are now actually being obtained in refineries operating from 500 to 1000 hp., and in these particular instances a greater gallonage of oil has been processed.

All of this has been accomplished simply by the application of the intelligence before mentioned, to firing method in order to secure correct combustion conditions in the furnace.

A correction of firing method not only saves a large amount of fuel, but in addition also produces a better-balanced combustion condition that will automatically increase efficiency and capacity without any expenditure other than effort. While it is probably impossible to attain efficiencies as high as 75 per cent with present equipment, in the old-style boiler houses the ratio of loss will still be a factor of considerable importance.

As a usual thing all boilers, in accordance with the usual custom, are connected to a main steam header, but in no instance are they protected by any semblance of a non-return valve. In but few plants will there be found flow meters or recording gages to indicate the output of the separate units. Therefore it becomes an impossibility to maintain any synchronization of load between them.

Dampers may usually be found in the uptakes, but they are never used. No gages are installed, either, to indicate the intensity of the draft. These two conditions afford a further potential loss in the following manner.

Due to the wide variation in heat demand as different grades of oil are processed, it is almost an impossibility for the boiler-house operator to foretell or determine a definite load factor for any particular period. It may be the case that a 150 per cent load demand will continue for a period of 12 hours or more and then drop to 50 per cent or less, and continue for a like period. These periods occur at irregular intervals and are dependent upon the quantities, etc., that are processed at a particular time. In order to be prepared for any emergency and satisfy a sudden increase in the demand, all boilers will be kept in operation at reduced steaming rates—with the result that at such times from 30 to 50 per cent of the fires will be entirely dead or the grates uncovered. The natural result of this condition is excessive air admission through the boilers, for the dampers will not be operated in keeping with the load. Furthermore two or more boilers may be carrying all of the load while the others are actually acting as condensers and absorbing steam from the system because of the absence of non-return valves to automatically cut non-producing units out of service.

It will generally be found also that all water fed to the boilers is regulated by hand. Frequently the water will just appear in the bottom of the glass. At such times the fireman will proceed to inject heavy amounts, which will probably be 100 per cent in excess of the boiler's steaming rate, thus again automatically creating within

the boiler a heat-absorbing instead of a heat-producing condition.

After the steam has been produced in a boiler house, whether it be efficiently generated or not, the refiner has still another heavy loss to absorb by the misapplication of the steam to refinery purposes. This also is reflected back to the boiler house and the coal pile.

Probably 40 per cent of the steam produced is used to operate pumps and engines. In many refineries all of the exhaust steam from these units is permitted a free escape to the atmosphere, or connected direct to sewers or condensed in large tanks of water. It is also frequently noted that the pumps have been in continuous use for years without ever having been repaired. As a result of this neglect, valves, pistons, and cylinders have become badly worn, and large volumes of steam are wasted in addition to those required to operate the equipment.

Control valves of equipment are frequently found so badly eroded by the wire-drawing action of the steam, that even when the equipment is not in service each of these small orifices exacts its toll from the boilers. Innumerable steam leaks of varying size, uninsulated lines, countless untrapped drips, all play an important part in the total load factor.

About 60 per cent of the steam produced in the boiler house is used either in the stills or for heating purposes. Herein lies a most important fact. Strange as it may appear, steam pressures in excess of 35 lb. per sq. in. absolute are not required nor are they necessary in any way in processing petroleum in the stills, provided the latter are correctly designed.

Method of Utilizing Every Heat Unit in Steam Generated and of Conserving Those Now Wasted Through Exhaust

In order to utilize every heat unit in the steam that is produced in the boiler house and conserve those which are now indiscriminately wasted through exhaust, the following brief outline of a method that has been developed and successfully operated is presented.

Pressures are increased on the boilers as much as insurance restrictions will permit.

All exhaust lines are connected to a low-pressure main header carrying as high a back pressure as will permit a sufficient differential to operate all of the pumps, etc. The back pressure, however, is never in excess of 20 lb. gage. Pressure-reducing valves are connected between the high- and low-pressure mains in order to maintain a predetermined pressure at such times as sufficient prime movers are not in operation to supply the amount necessary. These low-pressure mains are in turn connected to the stills and all other departments requiring heat of this character.

It is also desirable to introduce a superheater located in the still waste-gas flues and connect it to the exhaust or low-pressure mains before the steam enters the stills. The final temperature of the steam may in this way be increased several hundred degrees, at no cost whatever, from the heat that would ordinarily be wasted. Such a method will reduce the boiler-house load as much as 30 per cent by utilizing the heat that is wasted, and also cut the cost of fuel correspondingly. Probably one of the most economical phases of heat conservation as it applies to the boiler house is that of producing electrical power as a by-product of the steam used in processing.

A refinery will consume from 2000 to 20,000 kw-hr. of electricity per day. In a great many instances this power is now purchased at a rate dependent upon the load demand. There are a few refineries, however, that produce their power in this manner. In each of these the cost to produce a kilowatt-hour, including all operating and overhead charges, is from $0.038 to $0.08. With such a saving as this over purchased power, the capital investment for turbines, generators, switchboards, etc., is retired in a very few years.

As a concrete illustration of what can be accomplished in this manner, assume an electrical power consumption of 200 kw. per hour, a bleeder-type or single-stage turbine, operating non-condensing against an absolute back pressure of 35 lb. per sq. in., and the initial pressure of steam to the turbine at 175 lb. gage and 100 deg. superheat. The total heat in this steam is 1253.6 B.t.u. per lb. Admitting that the water rate of the turbine operating against such a back pressure will be somewhat high, we shall assume this rate to be 70 lb. per kw-hr. If all of the superheat has been dissipated by expansion through the generator, the heat extracted from the steam per kw-hr. will be $(1253.6 - 1166.8) \times 70 = 6076$ B.t.u.

If the steam is produced at an efficiency of 70 per cent from coal having a calorific value of 13,500 B.t.u. per lb. (dry basis), the power has been produced for slightly over $^2/_3$ lb. of coal per kw. and there is still the 70 lb. of steam per kw. remaining for processing work.

As a matter of fact, it should be stated that the daily records of several plants operating in this way show that there is at least 30 per cent of superheat still remaining in the steam after it has passed through the turbine. In such cases the actual coal consumption per kw-hr. is only a trifle over half a pound.

The practicability of such installation as has been outlined is particularly advantageous in a refinery from the fact that a large amount of power is necessary for pumping purposes in transfer of stocks from one department to another. It is therefore possible to so balance the power load with the steam load so that an excess of steam will be neither produced or wasted.

Savings Possible by Adoption of Proposed Plan

The plan, briefly outlined, is as follows: Install modern water-tube boilers, stoker or pulverized-fuel fired, and operate them at pressures of 250 lb. gage or higher. Connect these directly to bleeder-type or single-stage turbines and produce electrical power. Expand or reduce the steam through these units to the old steam-distribution system at its normal operating pressure, which is usually from 60 to 80 lb. gage. After this expanded steam has served the old equipment, such as pumps, the exhaust from these may be again used as previously outlined for heating, etc. The steam likewise may be used by expansion to any intermediate pressure desired for a particular process.

Recovery of condensate suitable for boiler purposes is the next and final important matter. In all of these plants 100 per cent raw make-up water is pumped from streams carrying high percentages of suspended vegetable and mineral matter, or else from wells, the water from which contains high percentages of scale-forming sulphates and carbonates. In order to reduce the scale formation in the boilers, various compounds are introduced occasionally with the feedwater, and this in time tends to increase the soluble-salt concentration in the boilers. Possibility of burned water surfaces from precipitated sludges with attendant damage is always present also, whereas the cost to conserve pure, clean condensate up to probably 50 per cent of the total amount of steam produced would pay out in a very short period of time by reducing the labor cost of scaling, by the heat the water contains, and by reducing the hazard to the equipment.

Surveys conducted in over twenty refineries indicate that an average saving of over $8000 per year per refinery in fuel alone is possible by simply changing the firing methods; that an average saving by conserving the steam now wasted will amount to approximately $8000 more per year per refinery; and that about $6000 or more per year may be saved by each refinery's producing its own electrical power; or a total saving per year of $22,000. No small refinery can therefore afford, under the prevailing competitive conditions of its business today, to continue operating old equipment with cheap labor. On the other hand, installation of modern equipment is indicated as an economic necessity, and the employment of trained engineers at a wage commensurate with the importance of the boiler house is of equal importance.

Discussion of Papers Presented at the Petroleum Session

THREE papers were presented at the Petroleum Session of the A.S.M.E. Annual Meeting, held on December 9, 1926, under the auspices of the Petroleum Division of the Society, H. S. Bell presiding. They were: New Methods of Lubricating Steel-Mill Machinery, by C. H. Bromley; The Boiler House in Oil Refineries, by H. A. Ross; and Modern Fire Fighting in Oil Refineries, by Frank A. Epps. Mr. Bromley's paper, which was published in the Mid-November, 1926, issue of MECHANICAL ENGINEERING, dealt with requirements in lubricating oils, characteristics of lubricants suitable for gears and journals, gravity- and pressure-type lubricating systems, rates at which oil should be supplied, etc. The papers by Messrs. Ross and Epps appear on the pages immediately preceding. A summary of the discussion on the three papers follows.

A New Method of Lubricating Steel-Mill Machinery

H. M. Brown,[1] discussing Mr. Bromley's paper on the above subject, wrote that in every industry there was no item that gave more concern or had more to do with the successful operation than bearings and lubrication and the proper care to insure continuity of operation. When The International Nickel Company entered in the field for the construction of a rolling mill at Huntington, West Virginia, for the rolling of monel metal and nickel products, they naturally were greatly concerned not only in obtaining the best metal that could be secured for the bearings throughout the mill, but the method of lubrication to be employed received careful consideration. At that time the old practice prevailed of using a gear compound in the gear housings as well as in the pinions, and some attempt had been made to use oil on the necks of the pinions, but using the gear compound on the pinions themselves.

When building the mills considerable care was given to the details of the construction of the housings for the pinions and gears, as well as to the lining of the bronze bushings to make it possible to use oil throughout. By careful and accurate machining of the gears themselves and operating them in a bath of oil, it was believed that considerably longer life and more satisfactory service would be obtained than under the system then in vogue.

In conjunction with one of the lubricating companies a complete lubricating system was devised for use on all of the mill equipment, which was the first complete installation of its kind in this country. The system as installed was practically along the lines outlined in Mr. Bromley's paper. Of course, some improvements in the pump and filter system had been made since the installation was completed, but in the main it was the same. The lubricating oil had been carefully watched, and in the merchant mill and sheet mill the same oil was now in use that had been put in the system when beginning operations five years before, and a careful test of the oil showed practically no deterioration, which spoke for itself of the excellent manner in which the system had operated.

G. B. Karelitz[2] wrote that it always had been his belief that large installations such as steel mills should use forced lubrication in their machinery. The present state of technique allowed the use of pumping equipment of a quality which would give a fairly high guarantee of uninterrupted service. The additional cost of installation and of added maintenance would in the long run no doubt be paid by the increased life of equipment and by a decrease in shutdowns due to bearing troubles.

In bearings of large size, or of high speed when heavily loaded, where oil-ring lubrication was used, the journals, in Mr. Karelitz's opinion, often received less oil than they could use, i.e., less than their pumping capacity. Though they functioned safely, the oil film maintained might be thicker with a liberal supply of oil.

As a safeguard against failure of lubrication in the plant due to damage of the main lines, a system might be recommended where the pressure line as well as the return line were laid out as loops around the plant. The oil was fed from the gravity or pressure tank into the pressure line, and the return line was connected to the precipitation tank. The ring pipes being provided with a sufficient number of valves, a breakdown of the line in one spot would not interfere with the continuous operation of the plant.

As there was seemingly some difficulty under the conditions of steel-mill machinery in guarding against water penetrating into the oil, it appeared advisable to use centrifugal separators or other means to remove the water. The use of such apparatus for this purpose was at present well developed. The purifier was of small capacity, receiving oil continuously at a low rate through a bypass from the main line and discharging it back after cleaning.

It had to be noted that marine practice using high-power and high-speed reduction gears showed practically no wear of the teeth over years of service with lubrication as described in the paper, i.e., when the oil was sprayed on the teeth just before they came into mesh.

In the case of gears operating in both directions, an adequate lubrication of this type required a double set of oil sprays.

When a water cooler was installed it was advisable to arrange this so that the pressure of the cooling water was, if possible, less, or at least only slightly higher, than the oil pressure, in order to prevent considerable penetration of water into the oil, should leaks occur, which was always possible in an oiling system.

Percy C. Day,[3] who discussed the paper orally, said that as representing manufacturers of heavy herringbone-gear installations which had been in operation for perhaps fourteen years in this country, his company naturally had acquired a fund of experience covering not merely steel-mill installations but the whole line of reducing gears, from the smallest speed reducer to the gears that were used on high-power turbine-driven warships and like equipment, involving extremely high powers condensed into small compass and very high tooth speed.

It was difficult to reconcile the needs of the different kinds of speed reducers to one class of lubricant or one system of lubrication. In the high-speed type of gear, the turbine gear, there was no possible solution but to use oil throughout. It would be entirely impractical to attempt to design installations so that the lubricants could be separated.

In steel mills, however, his company had installations operating where the tooth speeds of the gearing ranged all the way from 5000 ft. per min., down to as low as a very few hundred. In the one case the duration of the gear contact was very brief; in the other it was of much longer duration, and it seemed very logical to suppose that if the metallic surfaces of the teeth were to be kept out of contact, something heavier would be needed than would be adequate for the lubrication of the bearings.

To show how far one could go successfully with separated systems, about three years ago Mr. Day's company had installed a 5000-hp. drive in a rail mill in Alabama. The conditions had called for a high-speed motor. The gear speed was a little over 4000 ft. per min. Those gears were being lubricated by compound lubricant, dipping in the compound to a depth of about two inches. The arrangements for separating the oil in the bearings from the compound in the gears had of course to be elaborate and complete, and in most of the company's work in recent years a great deal of attention had been devoted to this problem of complete separation, so that the most suitable viscosity of lubricant for both the bearings and the gears could always be chosen.

In large installations of that kind the journal pressures and journal speeds were invariably high, which meant that the oil used on the bearings was not merely for the purpose of lubricating them but also for cooling them, and a considerable volume of oil had to be circulated to keep the bearings cool.

The viscosity-temperature characteristics of most heavy-bodied oils showed a very rapid drop in viscosity with a comparatively slight increase in temperature. Consequently the oil chosen had to be capable of being cooled without great difficulty. In his experience with marine-turbine installations he had found that the difficulty of cooling increased very rapidly with the initial viscosity of the oil, and after a good many experiments the general conclusion arrived at was that for a heavy bearing surface, with fairly high journal velocities, say, from 25 to 100 ft. per sec.—in steel-mill work, up to about 40 or 50; in turbine work, much higher—using an oil with a viscosity of around 500 or 700, very good results were obtained because it was possible to keep that oil approximately at the temperature aimed at, and if a very high-viscosity oil such as 1000 or 1200 were used it would be much more difficult to cool, it was gummy, it stuck to the sides of the tubes if external water cooling was employed, and generally it would be found that those who specialized in oil coolers would specify a much larger size to achieve the same results with an oil of extra high viscosity. On the other hand, an oil of 1000 or 1200 viscosity at 100 deg. fahr., when it reached a temperature of around 130 or 140 deg., lost a great deal of that high viscosity. The same thing happened, of course, with compounds, but there was more left.

A compound was used in a heavy reducing gear, and although the temperature might reach 130 to 140 deg. fahr. (usually it was less), the viscosity of the lubricant that actually passed through the teeth was much higher than that of an oil. For that class of service his company had found compound lubrication to give the best protection.

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[1] Assistant General Manager, International Nickel Co., Huntington, W. Va.

[2] Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

[3] Chief Engineer, The Falk Corporation, Milwaukee, Wis. Mem. A.S.M.E.

THE BOILER HOUSE IN OIL REFINERIES

Discussing Mr. Ross's paper, E. P. Kiehl[4] said that emphasis ought to be laid on the fact that the statements in it applied only to a minority of the present boiler-house plants. The boiler-house plants of large refineries had done exactly what Mr. Ross had outlined ten years ago.

D. S. Jacobus[5] said that Mr. Ross had brought out, in an able and striking way, the present tendency to pay more attention to the industrial power plant and to the wastes that might occur in such a plant. At one time there was a feeling among steel manufacturers that they were making steel and not making steam, and that the securing of sufficient steam was all that need be considered. This represented the attitude of those in charge of most industrial plants in paying every attention to the manufacturer of their product and little to the economical development of the power used. As the art advanced and fuel became more expensive, wastes had been eliminated and more and more attention had been paid both to securing a better efficiency in the boilers and in the use of the steam after it was generated by the boilers. Operating the steam turbines with a high exhaust pressure and using the exhaust steam either in whole or in part for useful purposes, as described in the paper, often led to an important saving. Much had also been gained through employing a better class of labor. Great advances had been made, and the boilers in industrial plants, such as oil refineries and steel plants, were in some cases just as well fitted for the conditions to be met as those employed solely for developing and selling power. Dr. Jacobus thought that the author should be thanked for bringing the matter before the Society, as there were a number of older industrial plants where, say, 25 per cent or more of the fuel could be saved by proper operation and by employing the right kind of equipment, and the pointing out of possible saving contributed to the movement for conservation.

MODERN FIRE FIGHTING IN OIL REFINERIES

H. E. Ramsey,[6] commenting on Mr. Epps's paper, said that his company was able from its experience, to verify many of the statements which the author had made. For instance, they had had no case of tank fire due to lightning with the vapor-tight type of tank, but they had had a number of cases of fire on tanks with wooden roofs and other construction such as Mr. Epps had referred to.

The matter of ground resistance of tanks had also been, in his company's experience, exactly as stated by Mr. Epps: that the natural loam of the ground of tanks in these lines seemed to be more than adequate for all lightning purposes, without any artificial assistance.

It was not quite clear to him just what the connection was between Mr. Epps' suggestion that tanks should, if the ground was bad, be built on concrete slabs, and the danger of fire.

In connection with the lightning danger, he would mention the fact that there were manhole covers, gaging-hole covers, and also larger loose portions of tanks, such as floating Wiggins roofs, etc., which were not solidly connected to the tank or to the ground by any metallic connection. These portions were in danger, therefore, of having a poor contact at certain points, in certain positions, and as electrostatic condensers could contain fairly considerable charges which would be induced by the passage of a cloud overhead. In case of a lightning discharge anywhere near, the release of these charges, seeking an instantaneous path to the earth at a very considerable voltage, might cause a spark at some point of poor contact between the loose attachments and the tank. Such a spark could be avoided by means of a ground wire connecting these portions to the tank itself.

R. S. Hoffman[7] asked Mr. Epps how he regarded clay foundations, particularly for large tanks. There had been a theory that tanks placed on clay foundations, where possibly stumps were left in the original ground, would settle, and there had been instances where for some apparently undetermined reason the sheets in the first course had cracked right through the metal and not at the rivet holes, and he wondered whether the presence of stumps or perhaps large rocks contributed to that breakage.

In closing, Mr. Epps said in reply to Mr. Ramsay that where tanks were constructed on concrete foundations and the pipe lines were above ground, there was a possibility that the ground might be inadequate, and in such installations of course an artificial ground should be provided.

All loose metallic parts should be connected in an electrical manner. In the case of floating roofs, however, Mr. Epps did not believe the hazard would be considerable even if such a roof was not metallically connected to the tank shell, since there was practically no vapor space.

Replying to Mr. Hoffman, Mr. Epps said that he favored concrete foundations in cases where the ground might have questionable bearing power. Obviously, if the earth was good and solid and there was a clay base, there was no reason why a concrete foundation should be essential, provided the clay foundation was prepared well ahead of time and properly tamped. In some respects he believed that a concrete foundation aided in preserving the tank, in that it would keep moisture away from the tank bottom. As to the cracking of the tank sheets which Mr. Hoffman mentioned, he would attribute that to poor steel.

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[5] Advisory Engineer, The Babcock & Wilcox Co., New York. Past-President A.S.M.E.

[6] Atlantic Refining Company, Philadelphia, Pa.

[7] Superintendent of Shops, Standard Oil Co. of N. J., Elizabeth, N. J. Mem. A.S.M.E.

Hudson-Type Locomotive on the New York Central

DESCRIPTION of the first locomotive of the 4-6-4 wheel arrangement to be built in America. It was constructed by the American Locomotive Co. for the New York Central Railroad and will be used in high-speed main-line passenger service on the 20th Century Limited and similar trains where its added starting and horsepower capacity will permit a reduction in the number of sections on some of these trains which it is necessary to run with the present heavy Pacific-type motive power. The locomotive develops a maximum tractive force of 53,500 lb., including 10,900 lb. supplied by the booster, which represents a substantial increase in tractive force over the present Pacific-type locomotives.

As regards the boiler, the additional capacity of the four-wheel trailing truck was utilized to increase both the size of the firebox and the boiler capacity. It includes a type E superheater with 1965 sq. ft. of heating surface, which added to the 4491 sq. ft. of evaporating surface gives a total of 6456 sq. ft. of heat-transferring surface. The firebox has a grate area of 81.5 sq. ft. and is equipped with cast-steel grate bars, which account for a substantial reduction in weight.

The arrangement made for the location of the Elesco feedwater heater below the top of the smokebox shell is of unusual interest, in that it effects a material improvement in the appearance of the locomotive. The heater is supported on a shelf welded into the top of the smokebox just back of the front-end door ring. With the heater in place, the opening over the shelf is closed with plates which complete the circle of the front end so that only the ends of the heater are exposed beyond the curve of the smokebox shell.

Among the machinery details the four-wheel Commonwealth Delta type trailing truck is of greatest interest. This follows the principles of suspension and weight distribution of the well-known Delta type two-wheel trailer truck, with the driving wheels and both trailing-truck wheels on each side of the locomotive equalized together. The design is worked out in combination with the standard inside cradle casting, permitting the tractive force of the engine to be transmitted through the cradle extension of the main frame system to the engine and tender drawbar.

All steam pipes and valves as far as possible have been kept outside the cab under a turret housing over the top of the boiler in front of the cab. The steam valves in the turret are operated by extension handles which pass back through the cab wall where they are arranged in a neat line across the top of the firebox on an instrument board with each handle clearly labeled. With the exception of the air and back-pressure gages, all of the gages in the cab have been assembled on the instrument board. (*Railway Mechanical Engineer*, vol. 101, no. 3, March, 1927, pp. 139–141.)

Internal Friction in Solids

By A. L. KIMBALL, JR.,[1] and D. E. LOVELL,[2] SCHENECTADY, N. Y.

In connection with a test devised to determine quantitatively the amount of friction within the metal of a steel shaft, it was found that the internal frictional forces were totally unlike those of a viscous fluid, as assumed by many investigators, where the forces are greater the more rapid the deformation. Instead of this, the dissipative forces were found to be the same whatever the speed of deformation. The apparatus with which the tests were conducted is described, and the results are tabulated. Equations relating the variables involved are derived in the analysis of the problem.

THE present investigation is the outcome of a study, by one of the authors, of the effect of the internal friction within the metal of a steam-turbine wheel in dissipating vibration (1)[3] and also of the effect of internal friction within a rotor and shaft in producing shaft whipping (2). In connection with a test devised to determine quantitatively the amount of friction within the metal of a steel shaft (3), it was found unexpectedly that the internal frictional forces were totally unlike those of a viscous fluid, as assumed by most investigators (4), where the forces are greater the more rapid the deformation. Instead of this, the dissipative forces were found to be the same whatever the speed of deformation. A few investigators have appreciated this characteristic of internal friction (5), which was found to be general for all solids thus far

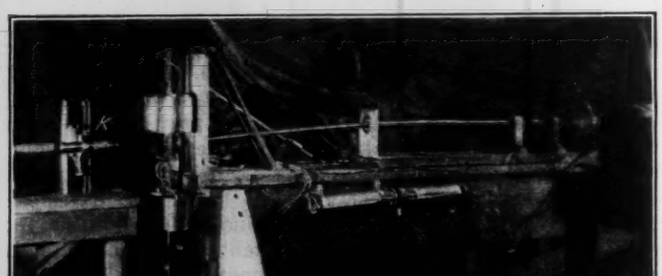

FIG. 1 PHOTOGRAPH OF THE APPARATUS

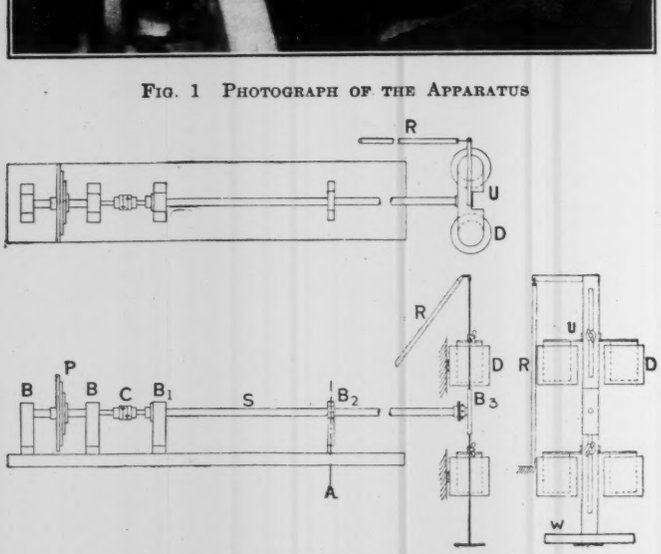

FIG. 2 PLAN AND ELEVATIONS OF APPARATUS

tested by means of a special experimental test to be described later in this paper.

METHOD OF TEST

Figs. 1 and 2 show a photograph and drawings of the apparatus used. The material to be tested was made in the form of a rod, usually $\frac{1}{2}$ in. in diameter and about 36 in. long. The rod was supported in two ball bearings, B_1 and B_2, and driven by an electric motor through the pulley P which was supported in the bearings marked B, the torque being transmitted to the rod by means of a small Oldham coupling C. The bearings B_1 and B_2 were so situated that more than half of the rod overhung. On the projecting end of the rod was another ball bearing B_3, on which was hung the frame U, which carried a weight W on the pan at its bottom. The rod was thus deflected downward, as shown in the photograph of Fig. 1, and at the same time it was free to revolve. The frame U carries four plungers which dip into four rigidly supported cups containing a suitable damping fluid. This proved an effective means of steadying the end of the rod during revolution, so that the amount of its deflection could be observed.

Fig. 3 shows the way the end of the rod was deflected in these tests. The deflection was not exactly downward but was displaced by the angle ϕ from the vertical, due to the internal friction of the revolving rod. As the rod revolves, the fibers parallel to its axis are carried around its axis, alternately up one side and down on the other. As they move up they stretch, and as they move down they shorten. Any frictional resistance to the process of lengthening results in tension, and resistance to the process of shortening results in compression. Consequently in this case the upward-moving fibers are in frictional tension (T_F, Fig. 4), and the downward moving ones are in frictional compression, C_F. For the direction of rotation shown in Fig. 4, the left-hand fibers are therefore in tension due to this cause. These frictional stresses are superimposed upon the elastic stresses, T_E and C_E, and just as the elastic stresses produce an upward reaction R_E, so the frictional stresses produce a transverse reaction. The forces R_E and R_F are components of the force which balances W exerted by the weight on the end of the shaft (Fig. 3). If the weight is removed, R_E and R_F vanish (neglecting the weight of the rod), so that both the elastic and frictional couples must vanish. If $\phi = 0$, $R_F = 0$, that is, no frictional force is present. This is the case when the rod has the weight on its end but is not revolving. When it is revolved, with the weight on it, a frictional force arises which causes a sideways displacement of W until R_F is just balanced. The magnitude of R_F is thus a measure of the internal friction within the rod. Its value is easily found when the amount of dis-

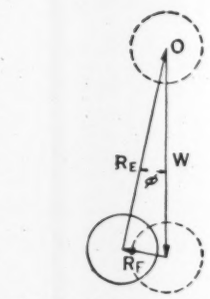

FIG. 3 VIEW OF WEIGHTED END OF SHAFT SHOWING SIDEWAYS DEFLECTION DUE TO INTERNAL FRICTION

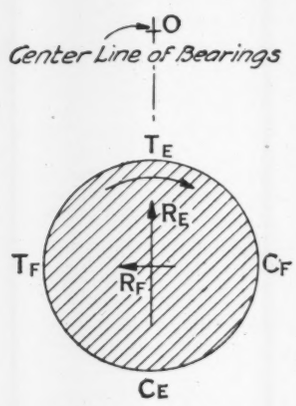

FIG. 4 CROSS-SECTION OF SHAFT SHOWING ELASTIC AND VISCOUS STRESSES AND THEIR REACTIONS AT THE END OF THE SHAFT

[1] Research Engineer, General Electric Company. Assoc-Mem. A.S.M.E.

[2] Research Engineer, General Electric Company.

[3] These, and similar numbers in parentheses, refer to the bibliography at the end of the paper.

Presented at the Annual Meeting, December 6 to 9, 1926, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

placement of the end of the rod from the vertical is known, together with the weight W. This sideways displacement of the rod was measured by means of a cathetometer (K, Fig. 1). This method of test has a peculiar advantage over those previously used for the determination of internal friction in solids, in that it gives the internal friction directly as a function of the frequency of the strain cycles. The frequency of the strain cycles in the revolving deflected rod is equal to its speed of rotation, because for each revolution every longitudinal fiber of the rod (except those along its axis) undergoes a complete cycle of extension and compression. Thus the frequency of the strain cycles is varied by varying the rotational speed of the rod. The method amounts to a refinement of the Wöhler bar test.

Internal Friction Independent of Speed of Performance of Strain Cycle

According to the classical theory of viscosity, which is often applied to solids (4), the transverse deflection of the revolving rod should be proportional to the speed of rotation. The first test was made on a rod of $3\frac{1}{2}$ per cent nickel steel with a view to observing the increase of the transverse deflection with speed, but no such change was observed over a speed range of from 2 or 3 up to 200 cycles a second. A definite deflection was present, however, as was found by reversing the direction of rotation of the rod. The amount of the transverse deflection could be increased only by increasing the load on the end of the rod, but was found for every load tried to be entirely independent of the rotational speed of the rod. This showed that for nickel steel the forces produced by friction within the rod are independent of the velocity of strain and that, for a given amplitude of strain, the frictional loss per cycle is independent of the speed of performance of the strain cycle.

Every solid thus far examined exhibits an internal friction which is independent of the speed of performance of the strain cycles.

Materials which exhibited a linear relation between internal friction and maximum stress were: swaged quarter-inch-diameter tungsten (up to its breaking point), maple wood, zinc, commercial rolled nickel, glass, celluloid (up to 560 lb. per sq. in.), and copper (up to 7000 lb. per sq. in.). For the other materials listed in Table 1 a straight line would lie among the points below the limit of proportionality only as an approximation. However, such a straight line represents the materials much better than any other single type of curve and affords the most useful comparison.

The effect of bearing friction upon the deflection in the rotating-rod test was negligible. Theoretical considerations show that the couples produced by friction are directly balanced by the torque applied. The application of exaggerated bearing friction produced no observable change in the deflection ϕ from which the internal friction was measured.

Definition of Coefficient of Internal Friction

A question which arises at this point in the discussion is how the coefficient of internal friction of a solid is best defined. To have definite meaning the coefficient of internal friction must be based upon a definite law of internal friction. From a study of a large number of curves of the revolving-rod test and also a study of the literature on this subject, the law of internal friction which most generally fits the facts and which at the same time is a simple one is

$$F = \xi f_m^2 \quad [1]$$

where F = frictional loss per unit volume per cycle at a particular point

f_m = amplitude of the stress cycle above and below zero stress at the point in question

ξ = internal friction constant = internal friction loss per unit volume per cycle unit stress amplitude. In the c.g.s. system of units this constant equals internal friction per cu. cm. per cycle per dyne of stress amplitude. In terms of inches and pounds, it equals internal friction per cu. in. per cycle per pound of stress amplitude. Table 1 gives values of this constant expressed in both systems of units for a series of solids.

Table 1 gives a complete list of the solids whose internal frictions have been measured thus far, no exception to the law of Equation [1] being found. All materials in this table, with three exceptions, are seen to be metals and alloys. But even for the three other materials, celluloid, glass, and maple wood, the same law holds. Glass is somewhat erratic, but there is no doubt as to the frictional loss per cycle being practically independent of the velocity of performance of the strain cycles, under the conditions of the experiment. Of the metals and alloys tested, tin and zinc are seen to have much higher coefficients of internal friction than the others. Monel metal and nickel, though very ductile, have little frictional loss.

TABLE 1 INTERNAL FRICTION OF VARIOUS MATERIALS

Material	Tan ϕ ($\times 10^{-3}$)	Elastic modulus lb. per sq. in. ($\times 10^{6}$)	Internal-friction constant: Inch-lb. units ($\times 10^{-10}$)	Internal-friction constant: C.g.s. units ($\times 10^{-15}$)
Celluloid	14.4	0.31	14500	21000
Tin, swaged	40.7	4.5	278	402
Maple wood	6.69	1.9	122	172
Zinc, swaged	6.30	13.7	14.4	20.8
Glass	2.05	9.1	7.1	10.2
Aluminum, rolled	1.07	8.4	4.0	5.7
Brass, cold-rolled	1.54	12.3	3.9	5.7
Copper, rolled	1.59	14.6	3.42	4.95
Tungsten, swaged	5.24	56.2	2.93	4.26
Swedish iron, annealed	2.50	27.4	2.88	4.16
Annealed phosphor bronze	1.01	17.2	1.85	2.67
Mild steel, cold-rolled	1.57	30.3	1.55	2.33
Molybdenum, swaged	2.19	50.2	1.37	1.95
Nickel, rolled	1.02	30.0	1.07	1.55
Nickel steel, $3\frac{1}{2}$%, swaged	0.73	30.0	0.76	1.10
Monel, rolled	0.454	25.8	0.55	0.79
Hard-rolled phosphor bronze	0.117	16.8	0.204	0.306

Discussion of the Law of Internal Friction: Equation [1]

It should be clearly understood that the internal friction studied in this paper is for small stress amplitudes, such as those which arise in a vibrating body where the stress amplitudes at all points in the body are comparatively low. If the stress range is so large that the elastic limit of the solid is approached, the internal friction begins to rise rapidly and the law of Equation [1] no longer holds. The plastic yielding characteristic of many solids above the yield point belongs to a class of internal-friction phenomena completely outside of the range of, and governed by different laws from, the phenomena studied by the authors of this paper.

The first column of Table 1 gives the value of tan ϕ. This is useful, because tan ϕ is a direct measure of the ratio of the frictional force to the maximum stress for any given point in the rod. It gives a direct means of calculating ξ, because it can be shown that

$$\xi = \frac{\pi}{E} \tan \phi \quad [2]$$

where E is the elastic modulus.[4] These latter statements are true only when the law of internal friction expressed by Equation [1] holds. With this law the ratio of the frictional force to the amplitude of the stress cycle is the same for every point in any vibrating body, because with this law the frictional force is a linear function of the stress amplitude, so the ratio is a constant for all stresses up to the limit of proportionality. Furthermore this law gives a logarithmic decrement of vibration amplitudes, because the frictional loss per cycle is proportional to the square of the amplitude. Thus this law of internal friction and the old viscosity law give the same law of decrement of vibration amplitude. The values of ξ obtained from Equation [1] give a very useful means of comparing the internal frictions of solids, whereas constants based on the old idea that the viscosity of a solid is like that of a liquid are completely misleading.

These statements are proved only within the range of the tests outlined in this paper, but the authors are of the opinion that a law of the type represented by Equation [1] will be found to hold over a very wide range of frequencies.

The only case, to the authors' knowledge, where measurements have been made for very high frequencies is that of the experiments of Quimby (6). He uses the old liquid-viscosity law in interpreting his results and obtains constants smaller than those of previous investigators in the same ratio as his frequencies are higher than theirs. On the basis of the author's law, however,

[4] The derivation of this equation is given as an appendix to the complete paper.

Quimby's results and those of previous investigators give constants of the same order of magnitude.

Attention should be called to the fact that for frequencies of the order of those in bells and in bodies which respond with a prolonged ring when struck, the law of Equation [1] shows that such a ring is perfectly possible, whereas on the basis of the old liquid-viscosity law, using the constants of previous investigators for that law (except Quimby's constants), no ring is possible. A bell would be aperiodic, as if made of putty. This is mentioned by Quimby in his paper.

VIBRATION TESTS

In order to be certain that forces other than those of internal friction were not responsible for part of the deflection ϕ, several of the same rods which were given a rotation test were subjected to a vibration test, as shown in Fig. 5. The heavy iron bars B, each three feet long, were clamped to the end of the rod to be tested by means of the clamping device shown enlarged in the figure. The system was then suspended by the two flexible and practically frictionless cords, C. The ends of the heavy bars were vibrated toward and away from each other so that the rod was deflected to and fro in a horizontal plane at the natural period of vibration of this system.

This arrangement was used because the strain cycles of individual fibers were longitudinal like those in the rotation test, although the stress distribution was somewhat different. The internal friction was approximately determined for different vibration amplitudes

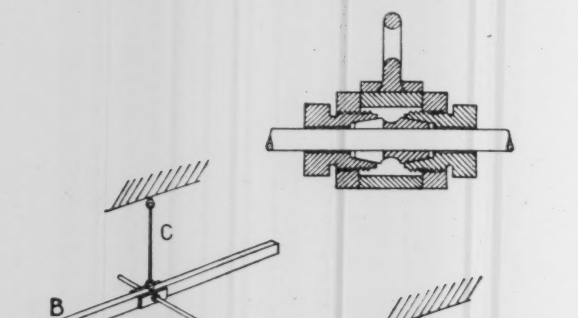

FIG. 5 APPARATUS FOR VIBRATION TEST, INCLUDING SECTION OF DEVICE FOR CLAMPING ROD

by decrement observations. Some results of these observations for steel (see Fig. 6) show the decrease of vibration amplitude with time. Curves of a similar character were obtained for brass and copper.

It is easily shown, on the basis of the internal-friction law of Equation [1], that the internal-friction constant ξ is given by the expression

$$\xi = \frac{1}{Ef}\left(\frac{dy}{dt}\Big/ y\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots [3]^5$$

where E = Young's modulus
f = frequency of vibration
y = ordinate of curve of amplitude decrease
$\frac{dy}{dt}$ = slope of this curve at the point y.

The ratio $(dy/dt)/y$ should be a constant along the entire curve for a true logarithmic decrement. This is not exactly true, though very nearly so for the case of steel.

Table 2 shows values of ξ for these materials determined by the rotational test compared with values determined from these curves.

[5] The derivation of this equation is given in an appendix to the complete paper.

The check is as close as expected. The constants for the vibrating rods are higher than those for the same rods when revolving, but bear approximately the same relation to each other. Considerable energy was dissipated by surface friction in the clamps.

TABLE 2 VALUES OF INTERNAL-FRICTION CONSTANT FOR BRASS, COPPER, AND MILD STEEL

Material	Internal-friction constant in inch-pound units: Revolving rod ($\times 10^{-10}$)	Internal-friction constant in inch-pound units: Vibrating rod ($\times 10^{-10}$)
Brass	3.93	7.04
Copper	3.42	6.97
Mild steel	1.62	5.3

APPLICATION TO FATIGUE TESTS

A method similar to this has been used in the study of the fatigue of metals (7). It is possible that an apparatus of this type might prove of considerable value in determining the fatigue limit of

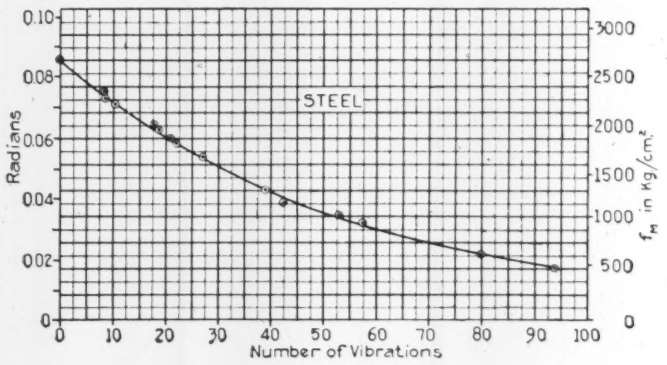

FIG. 6 CURVE SHOWING RATE OF DECREASE OF AMPLITUDE FOR STEEL ROD OBTAINED FROM APPARATUS OF FIG. 5

materials, because of the ease with which the sudden rise of internal friction at the yield point is located.

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(6) S. L. Quimby, *Phys. Rev.*, vol. 25, April, 1925, pp. 528–573.

(7) A similar method was used by Wöhler in investigations of fatigue failures, but not for the study of internal friction arising from strains much below the yield point of the material. See *Engineering*, vol. 115, 1923, pp. 698–699.

Discussion

IN A WRITTEN discussion H. F. Moore[6] and N. P. Inglis[7] pointed out that the authors had proposed a form of equation which seemed to be readily applicable to the study of the dying out of vibrations in a member. Reference (7) in the paper was evidently to the work of Professor Mason at the University of Liverpool. In his tests of energy loss in a specimen under cycles of stress, Mason secured sensitivity, not by the use of a long, slender specimen, but by the use of the optical-lever principle to measure deflections, horizontal and vertical. He used a rotating specimen subjected to a constant bending moment over a considerable por-

[6] Research Professor of Engineering Materials, University of Illinois, Urbana, Ill. Mem. A.S.M.E.

[7] Walker Engineering Laboratories, University of Liverpool, England. Holder of Robert Blair Traveling Fellowship in Applied Science and Technology.

tion of its length, and took extreme precautions to insure freedom from vibration while the specimen was running.

The materials tested by Mason included 0.37 per cent carbon steel and 0.13 per cent carbon steel. He was primarily interested in the *energy* lost in mechanical hysteresis, and made no attempt to derive any expression for the coefficient of internal friction. He did not find evidence of hysteresis loss at low stresses, but other English investigators, especially Guest and Lea,[8] did find evidence of such loss at very low stresses. Probably there was some loss under low stresses, but its detection was a matter of sensitivity of apparatus, and its magnitude might change after many thousands of cycles of stress.

The authors' statement that forces produced by friction within the rod were independent of the velocity of strain, and, for a given amplitude of strain, the frictional loss per cycle was independent of the speed of performance of the stress cycle, was a confirmation of the work of other investigators. Especially was this true of the work of Rowett,[9] who found that the area of the hysteresis loop (i.e., the work lost per cycle) depended only on the range of stress and not on the speed of reversal. The authors' conclusion that monel metal and nickel, although very ductile, showed little "frictional loss," raised the question of the part ductility played in these and in other similar tests. The note on the significance of internal friction in connection with fatigue failures of metals was of interest. In the tests of Mason, and of others, an attempt was made to locate the fatigue limit by means of a sudden increase in hysteresis or internal friction which was supposed to occur at the fatigue limit. The apparatus used in Mason's tests was designed to make "running deflection" tests, i.e., tests in which rotating-beam specimens were run for several thousand cycles at each of a series of loads, the deflection of the running specimen under each load being carefully measured. The stress at which the load-deflection diagram departed from a straight line had been found by some investigators to agree fairly well with the fatigue limit for a number of ferrous metals.[10] Later tests, especially those on cold-drawn non-ferrous metals,[11] threw doubt on the general reliability of this "running deflection" test for endurance limit. In the tests by Mason for both the 0.37 per cent carbon steel and the 0.13 per cent carbon steel the limit of proportionality under static load was found to be appreciably higher than the fatigue limit as determined by tests to destruction, and the departure of the "load-running deflection" diagram was found to occur at a stress lower than the fatigue limit. The appearance of lateral deflection indicating appreciable internal friction was at even a slightly lower stress. From a plot of values of this lateral deflection for the 0.13 per cent carbon steel it was seen that there was no definite "break" in the curve at the fatigue limit as determined by tests to fracture.[12] The rise-of-temperature test used at Illinois was another test, which like the "running deflection" test, showed the occurrence of marked slip in the specimen. This test, while giving fairly good results for the fatigue limit of rolled ferrous metals, was not found satisfactory for non-ferrous metals. For cold-worked non-ferrous metals the rise-of-temperature test gave values *above* the values determined for fatigue limit by tests to fracture.

T. McLean Jasper[13] wrote suggesting that with rods of the identical materials but of much thicker diameter, with the same length and loading conditions, the so-called internal friction constants might be materially changed. This reasoning was partially based upon some static results obtained by Mr. Jasper on the elastic constants of materials, as compared to the same elastic constants obtained dynamically, and also upon the report of Professor Jenkin[14] on fatigue limits of steel, using a very high frequency of stress alternations. The endurance limits in this case were very much higher than those found at low frequencies. The reasoning also was based partially on the fact that elastic hysteresis under repeated stress varied materially from the first cycle up to the hundred-million cycle. Much of this variation had been attributed to the relief of internal stress. Fatigue hysteresis much below the endurance limit showed conclusively after the hundred-million cycle that the value of the energy of the loop became almost negligible as compared to this value when such a test was started. Whether or not such a condition indicated internal friction or gradual relief of internal stress, Mr. Jasper was not prepared to suggest, but due to the fact that internal stresses were unquestionably relieved by repeated stressing below the endurance limit, he had attributed this phenomenon largely to stress relief.

The rate of stress propagation, internal stress relief, and gyroscopic effects on bent specimens might have some bearing on the authors' method of measuring internal friction within the elastic range of materials. This could be partially determined by changing the relative volume of the specimens used.

In the determination of fatigue limits in various steels by the rise-of-temperature method the point of disproportional increase of the temperature seemed to mark the endurance limit. The point at which internal friction (although below the elastic limit of the steel) became important in this case indicated the endurance limit, as obtained in the fatigue machine, with a good degree of precision.

The authors' vibration tests representing the number of vibrations for a given amplitude should give values, when considered in conjunction with the appropriate elastic constants, which would bear some relation to the internal-friction constants given in Table 1, if the internal-friction constants were correct. This did not seem to be the case. This, of course, assumed specimens of comparable size. Each of the materials represented were cold-rolled, which suggested fairly high initial internal stresses.

J. B. Kommers[15] submitted a written discussion in which he offered the following picture of what went in a rotating specimen. Due to mechanical hysteresis in an axial-stress experiment, the deformation in tension was not zero even when the tensile load had been reduced to zero, but becomes zero only after a certain amount of compressive load had been applied. A consideration of a tension-compression hysteresis loop would make this obvious. In a similar manner, in Fig. 4 of the paper, when a tension fiber had reached the point of C_F it still had tensile deformation in it and would continue to have it until part of the quadrant from CF to CE had been traversed. For the same reason, when a compression fiber reached T_F it would still have some compression deformation in it, and would continue to have it until part of the quadrant from T_F to T_E had been traversed. For this reason the neutral axis, instead of being horizontal in Fig. 4, made an angle with the horizontal, so that the axis fell in the second and fourth quadrants. It was bending about this neutral axis which caused a vertical and also a lateral deflection.

S. Timoshenko[16] wrote stating that the phenomenon of lateral deflection had been explained by Dr. Mason in his paper published in *Engineering* in 1923, wherein he had connected lateral deflection with internal friction or hysteresis. Other experimenters also had been interested in this question. In Germany, Benowitz published a paper in 1920, basing his conclusions on the same assumption as the authors, that the hysteresis loops for various loads were geometrically similar. In such a case the loss of energy would be proportional to the square of the load. Schenck also adopted the same method, employing a special machine which used the measurement of lost energy for predicting the endurance limit. Schenck had compiled[17] special tables for the lost energy of various materials. It would be interesting to compare his results with those of the authors.

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[8] Proc. Royal Soc. A., vol. 93 (1916–17).

[9] See reference (5) in bibliography appended to paper.

[10] H. J. Gough, Improved Methods of Fatigue Testing, *The Engineer* (London), Aug. 12, 1921.

[11] Bulletin 152, Engineering Experiment Station, University of Illinois, p. 61.

[12] At high stresses the lateral deflection tended to increase with an increase of the number of cycles of stress, but usually attained a constant value after about 2,000,000 cycles of stress—if the specimen lasted that long. The total amount of work absorbed during a fatigue test might be calculated from these measurements and had been found to increase as the range of stress was reduced and apparently might be infinite when the range was lower than the fatigue limit.

[13] Director of Research, A. O. Smith Corp., Milwaukee, Wis. Mem. A.S.M.E.

[14] Of the University of Oxford. Discussed at the last Toronto meeting of the British Association.

[15] Associate Professor of Mechanics, University of Wisconsin, Madison, Wis.

[16] Research Engineer, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

[17] Published by Lerthe in Stuttgart.

In their closure the authors stated that they were familiar with the work of Mason, which was mentioned both by Professors Moore and Inglis and by Professor Kommers. This work had first been called to the authors' attention at the British Association Meeting in the summer of 1924, and it had at once been recognized that his method was similar to that used by them in their paper; namely, the Wöhler bar method, although the measurements had not been made with the purpose of determining internal friction below the elastic limit.

Mr. Jasper's suggestion about using a larger rod, was a very good one and the authors were now planning to make such experiments. They were aware that hysteresis diminished with the number of cycles when the stress amplitude was below the endurance limit, but in their experiments this change had taken place in the first few cycles and remained constant for 100,000 cycles in several materials.

Since writing the paper, it had been found that Equation [13] reduced to δ/E, where δ equaled the logarithmic decrement of the vibration; that was, the log$_e$ of the ratio of the larger to the smaller of any two successive amplitudes during the decreasing vibration on the basis of the assumed law of Equation [1], which required a logarithmic decrement. This ratio must necessarily be constant.

Dr. Timoshenko had mentioned the fact that a similar law of internal friction loss was proposed by Bennewitz. This work of Bennewitz was referred to in the bibliography of the paper as representing one of the few which showed appreciation of the true nature of hysteresis in solids. His mathematical analysis was interesting, but the authors had been unable to make it check experiment for such a substance as celluloid, although it did appear to work for many other materials.

The Bunau-Varilla Water-Sterilizing Process

THE inventor of this process is well known in this country, particularly through his connection with the original scheme of digging the Panama Canal. During the war he was in charge of the water supply at Verdun, and for the purpose of sterilization he employed chlorine, using from 10 to 40 lb. per million gallons. Apparently there was no dechlorination, and complaints regarding the taste of the water were so strong that an effort was made to ascertain by experiment if the chlorine could be reduced sufficiently to render the water palatable without diminishing the sterilizing effect to any appreciable extent. This led ultimately to the development of a process which was not finally completed until after the war, and in which satisfactory results could be obtained with a dose as small as 3.2 oz. per million gallons.

Three years ago Rheims, France, which was suffering from typhoid fever in epidemic form, decided to install a plant on this system. The town has a population of 100,000 persons and the cost of installation was, it is reported, only 3000 francs—which, at the present rate of exchange means less than $125—while the daily cost of working is given at from 7 to 10 francs (say, 25 to 40 cents). The results obtained appear to be certainly astonishing. According to the testimony of the Director of Public Health of the city, there has not been during the three years the plant has been in operation, a single case of typhoid fever of local origin, whereas before it was put to work the number of deaths due to typhoid was 5 per cent of the population per annum.

Then, again, Carcassonne, having heard of the success at Rheims, installed a similar plant in 1925. That interesting old walled city had, from time immemorial, suffered from epidemics of typhoid fever, attributed to the drinking water drawn from the river Aude, which was the only source available. After the plant was got to work the epidemics of typhoid fever entirely disappeared, but they broke out again when, for some reason or other, the plant ceased to operate, though they disappeared once more when the treatment was restarted. Last year the system was, we understand, adopted with success, first at Monte Carlo and then at Sables d'Olonne, where ozone treatment had previously been used, at Aix-les-Bains, and at Compiègne.

The fact that sterilization of polluted water could be effected with such minute doses of water caused Bunau-Varilla to think that the action must be physical and not chemical, and eventually, after a long study of the problem, he was led to the belief that it was due to ultra-violet or similar rays. He was partly led to this conclusion by the fact that the effect is, he claims, instantaneous. The introduction, he says, of an infinitesimal quantity of chlorine into water will instantly destroy all bacteria in the immediate vicinity of the point of addition of the chemical, while in an extremely short space of time the whole volume of water is sterilized. He asserts that the ultra-violet-ray theory is proved by the fact that water, after sterilization by his process, assumes a radioactive quality which is sufficiently pronounced to destroy bacteria that are introduced into it. Furthermore he claims that the theory is proved to be correct for the following reasons:

a If a tube of quartz containing some water be immersed for part of its length in a bowl containing polluted water—not deeply enough, of course, for the two fluids to mingle—and if chlorine in the minute proportions he recommends be added to the water in the quartz tube, then the bacteria in the bowl will all be destroyed. That, he maintains, shows that the action must be due to something which can get through the quartz, and points to that "something" being ultra-violet rays or rays of even shorter wave length.

b The effects are even more pronounced in the dark than in daylight, which, he points out, is a characteristic of ultra-violet-ray action.

The original article shows the arrangement of the plants at the two cities referred to.

This method of water sterilization does not appear to have received, as yet, a permanent name. First it was called the "Auto-Javellization" system, after the name of Eau de Javel, under which designation commercial chlorine is sold in France. That name was changed to "Verdunization," in memory of the town of Verdun where it was first employed, and now M. Bunau-Varilla proposes to call it "sterilization by radiolysis" or the "radiolytic system." He believes that it is capable of other developments beyond the sterilization of water, and suggests that it may be possible to adapt it for the destruction of bacteria in sewage.

Chlorination is used extensively in the United States, the dose varying from 2 to 5 lb. per million gallons as compared with 3.2 oz. in the French process. In America it has been found that if the dose be lowered below the standard practice, complete sterilization no longer results, even though the amount used may be greatly in excess of what Bunau-Varilla uses. It would appear, however, that the Bunau-Varilla process works only when his minute doses are employed. (*The Engineer*, vol. 143, no. 3721, Mar. 4, 1927, pp. 234–235, 3 figs.)

Heat Transfer from Steam to Heavy Fuel Oil

CONSIDERABLE data are in the hands of manufacturers of oil heaters on the heat transfer from steam to medium and light fuel oils, but the field of research for the heat transfer to heavy oils is not so well covered. For that reason tests were made in which a heavy Mexican crude oil of about 11 deg. Baumé was used.

The data of tests are presented in the form of curves and tables, certain assumptions having been made in order to arrive at results. Among other things, the relation between the velocity v of the oil through the heater in inches per second and the outlet temperature t_0 of the oil were determined. Next were determined the relation between the velocity of flow V and coefficient of heat transfer K, and the resulting curve is given in the original article. This curve shows values of K from about 10 B.t.u. at a flow rate of 480 lb. per hr. to 77 B.t.u. at a flow rate of 2400 lb. per hr. These are average figures for steam pressures from 5 lb. to 210 lb. per sq. in. for steam slightly wet, and an oil inlet temperature of 70 deg. fahr. The relation is expressed by a particularly straight line with a coefficient appearing to decrease slightly with increasing steam pressure. This curve would indicate that the intermediate flow rates show fair agreement, but that the lowest and highest show variations from the general law for which no explanation is apparent in the test figures. (G. R. McCormick and H. Diederichs (Mem. A.S.M.E.) in *Bulletin of the Engineering Experiment Station, Cornell University*, no. 7, Feb. 1, 1927, pp. 2–20, 11 figs.)

The Panama Canal Diesel-Engined Power Plant

Details of Design and Data of Tests of Plant of 12,375 Hp. Peak-Load Capacity, Comprising Three of the Largest Diesel Engines Yet Built in America

IF A SURVEY is made of the various changes taking place in the power-plant field, one cannot help but be impressed with the tendency toward the use of larger units and the successful attainment in the securing of higher operating efficiencies. While this is true with all types of modern prime movers, it is especially noticeable with the Diesel engine. Aside from a marked growth in sizes in which this engine is now being built, there are also being opened many new fields of service for which it is used.

On January 23, 1925, the Panama Canal Commission awarded the Nordberg Manufacturing Company, of Milwaukee, an order for three direct-connected Diesel generating units of 2500 kw. capacity each. In a period of about two years these three engines were designed, built, completely erected, tested, accepted, and shipped, and final erection at the Canal practically completed. All three engines are now in service.

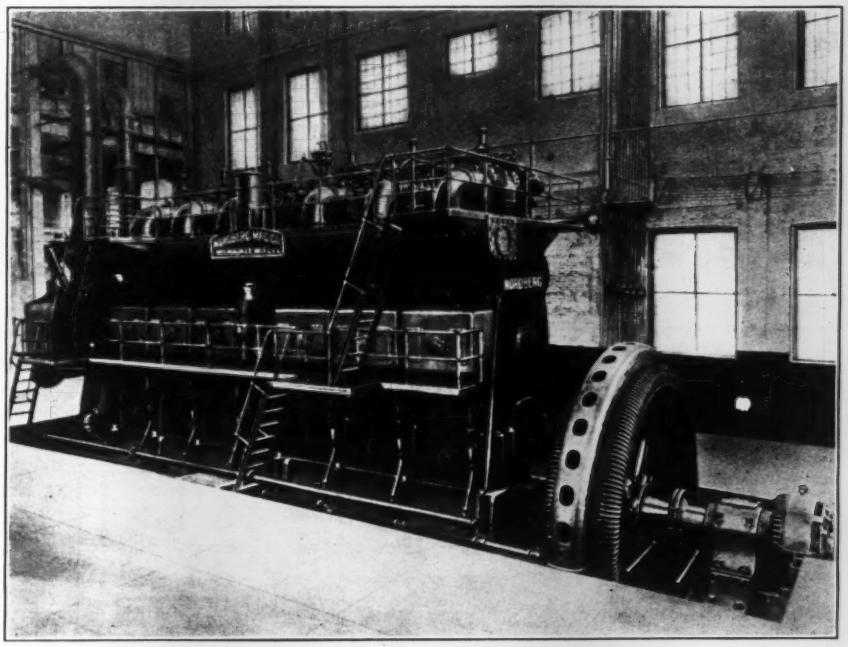


FIG. 1 ONE OF THE THREE 3750-HP. DIESEL ENGINES FOR THE PANAMA CANAL IN THE PLANT OF THE BUILDER

Each of these three units is of the six-cylinder, two-stroke cycle, single-acting, air-injection type, having cylinders of 29 in. bore with 44 in. stroke, operating at 125 r.p.m. and direct-connected to a 3125-kva. flywheel-type Allis-Chalmers generator (2200 volts, 25 cycle) with direct-connected 45-kw. exciter. These three engines when carrying the 10 per cent overload, which is guaranteed for a period of one hour, make the canal installation the largest Diesel-engine plant on the American Continent, having a peak-load capacity of 12,375 hp. The company had previously installed a 9400-hp. plant at Nacozari, Sonora, Mexico, and one of 6900 hp. at Warren, Arizona, and the long and satisfactory operation records of their engines were known to the Panama Canal engineers.

The power required for the Canal is ordinarily supplied by a hydroelectric plant located at the Gatun spillway. Due to lack of water supply during the dry seasons or if for other reasons the water-power plant should become inoperative, some form of standby service must be supplied. Heretofore this has been furnished by a steam station located at Miraflores consisting of an oil-fired boiler plant and three 1500-kw. turbines. This plant was built during the construction period of the Canal and had about reached the limit of its usefulness. Miraflores is the distributing point for power for the Pacific locks and is connected with the water-power plant at Gatun by a transmission line thirty miles in length. This transmission line is liable to damage by lightning so common in that locality and also to landslides in a portion of the country which it crosses.

After it had been decided to install a new standby plant, two principal questions had to be decided: first, location, and second, the type of power unit. The location was not difficult since the Miraflores substation was supplied with the necessary switch gear and locating the plant there would require no additional expenditure for such equipment.

In the selection of the type of power unit, three plans were considered:

1 To build a hydroelectric plant at Miraflores consisting of two 1000-kw. units and operate on water drawn from Miraflores Lake. This had the advantage of cheapness, but presented a serious objection owing to the shortage of water during four months of the year. Consequently it was rejected.

2 A combination hydroelectric and steam plant was next considered. It was planned to use water power during the rainy season and the steam plant when the hydroelectric plant could not carry the load. To pick up this load instantly would mean that a full head of steam would have to be carried at all times, which of course meant the burning of a considerable amount of fuel, even though no power was being developed; also if the boilers were cold, all Canal activities would have to stop for a period of two hours or until the plant could be put in service, which of course was out of the question.

3 The next type of unit considered was the Diesel engine, which eliminated all the objections of the other two. It could stand idle for months without requiring fuel, yet be ready for service on a moment's notice. While on test in the builder's plant it was found that the engine could be started and a load of 2500 kw. applied in 32 seconds.

Using Diesels for this service will result in a considerable saving in that no standby fuel will be required, also the operating labor cost will be considerably decreased. The very fact that Diesel engines were chosen for this important standby service and at times will be the sole source of power for the operation of the Canal equipment, is indicative of the perfect confidence now placed in the operating characteristics of the Diesel engine by those who are in a position to know its possibilities.

The new power plant at Miraflores is pleasing from an architectural viewpoint, being of concrete construction built around a structural-steel frame with inside dimensions of 78 ft. × 135 ft. Lengthwise it is divided into five bays, the first being occupied by offices, tool room, etc. One unit is placed in each of the next three bays, while the fifth is reserved for a future unit. The engines are placed with shaft centers 27 ft. apart and 15 in. below the engine-room floor. The distance from the floor to the lower side of the roof trusses is 45 ft. 6 in.

Ample natural light is afforded by large windows arranged for operation by push-button control from the engine-room floor. Ventilation at the upper portion of the structure is also provided. All the units are served by a 25-ton traveling crane.

The basement, which has a headroom of 13 ft., contains the auxiliaries, including the fuel and lubricating-oil equipment, pumps, auxiliary air compressor, etc.

Concrete mufflers with concrete stacks extending for a considerable distance above the roof are provided for each engine. A water spray at the muffler entrance cools the exhaust gases and keeps the muffler temperature low. The water level in the muffler

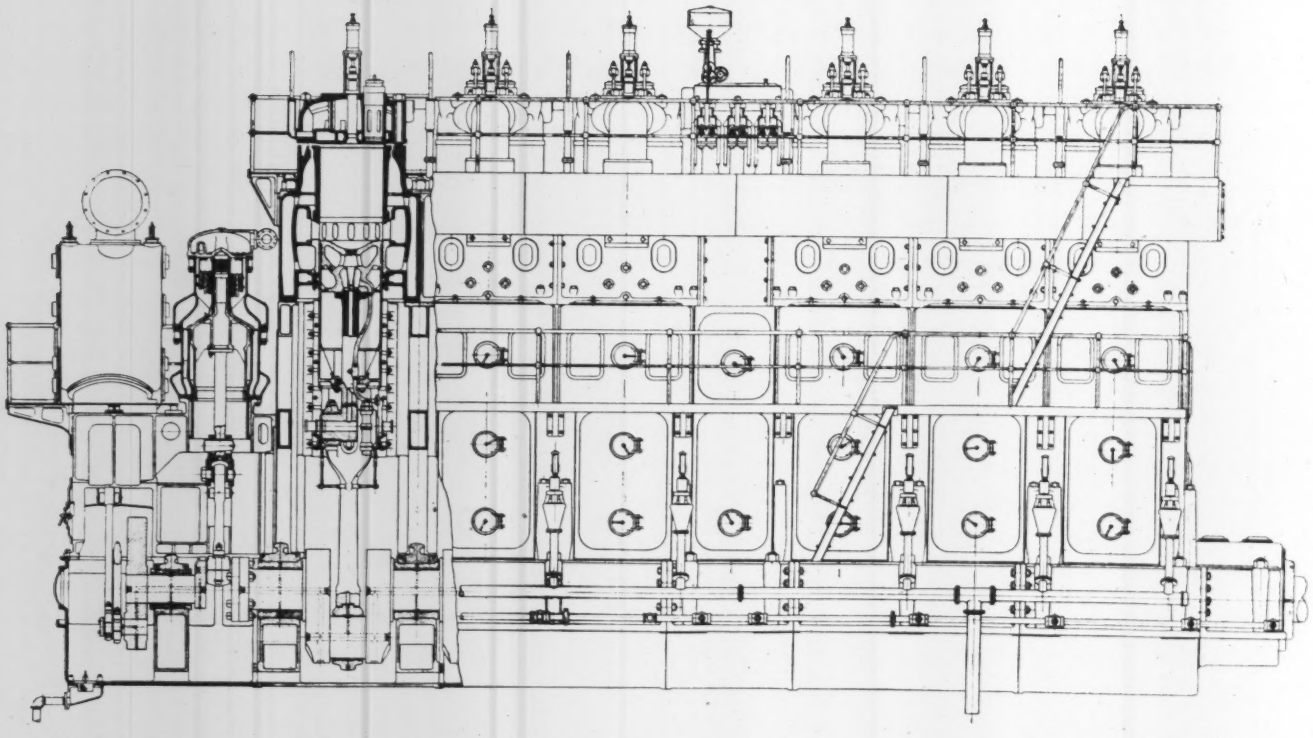


FIG. 2 FRONT VIEW OF ENGINE SHOWING A CYLINDER, THE AIR COMPRESSOR, AND PART OF THE SCAVENGING PUMP IN LONGITUDINAL SECTION

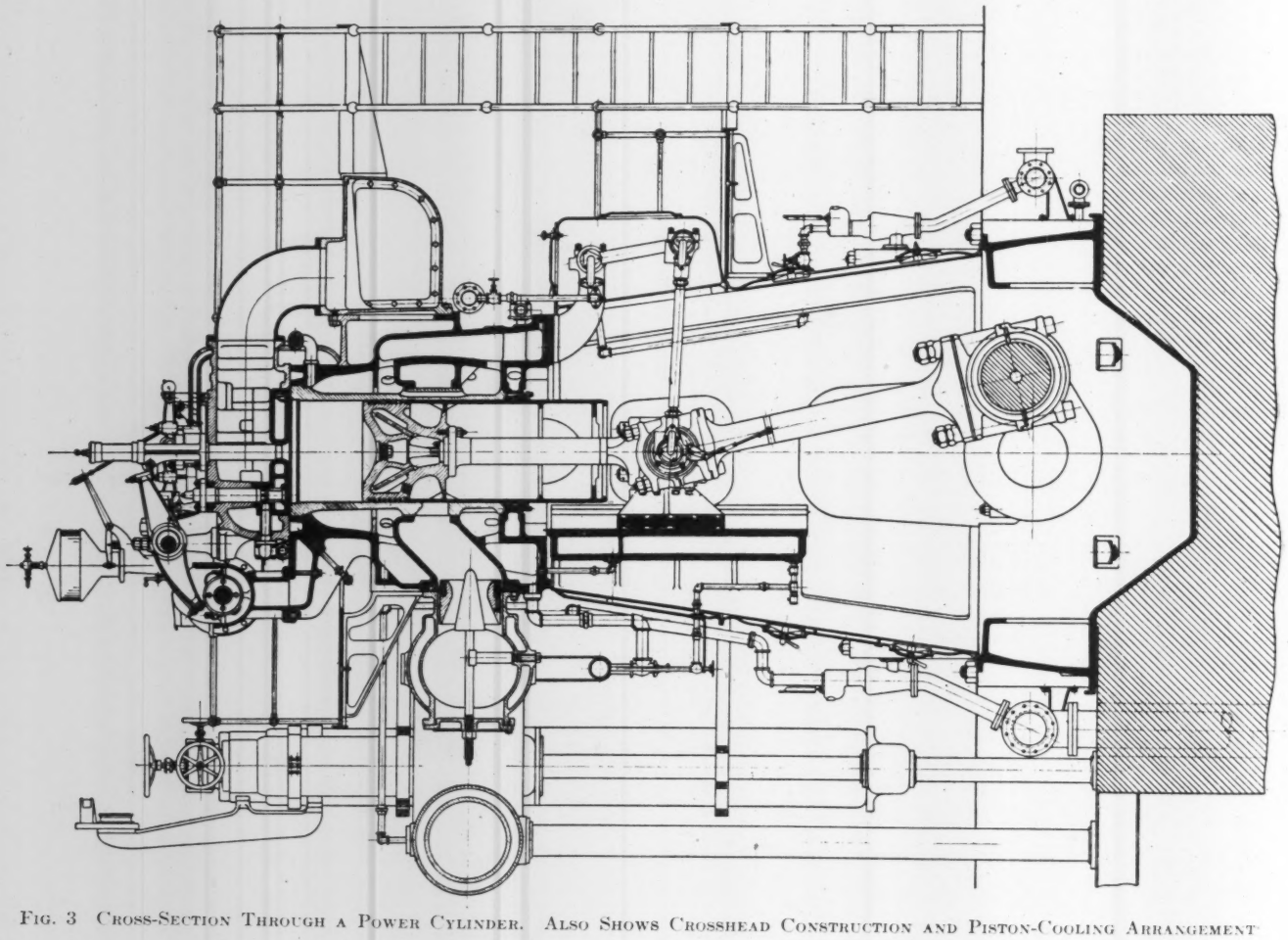


FIG. 3 CROSS-SECTION THROUGH A POWER CYLINDER. ALSO SHOWS CROSSHEAD CONSTRUCTION AND PISTON-COOLING ARRANGEMENT

is kept constant, but should it rise, a float-operated warning bell notifies the operator.

DESCRIPTION OF DESIGN

The engines are of the full Diesel, air-injection type and operate on the two-cycle principle. An idea of their construction can be gained from Figs. 2 and 3. On the end of the bedplate farthest from the generator are the two double-acting V-type scavenging pumps equipped with Nordberg automatic plate valves and driven by a single crank at the end of the crankshaft. Between the scavenging pumps and the No. 1 power cylinder is the three-stage compressor, which furnishes the blast air for fuel-injection and starting purposes; this also is driven by a separate crank. Next come the six power cylinders with the regular complement of injection and starting valves. The three cylinders at the generator end are equipped with air starting valves, these being rendered inoperative as soon as the engine begins to function on its own power.

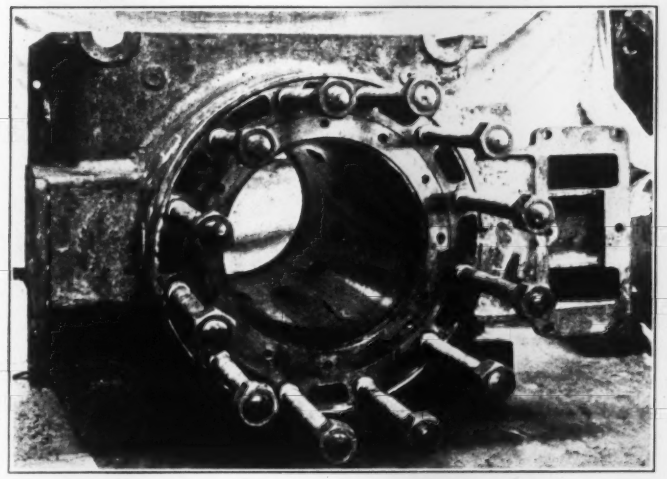


FIG. 4 CYLINDER CASTING WITH LINER IN PLACE

The cylinders are mounted on A-frames, which in turn are bolted to the bedplate. These frames are securely tied together at the back by the crosshead guides, on which slide the crossheads, these being of the slipper type. The crosshead guides are water-cooled. In addition to the cylinders being bolted to the frames, each is bolted to the one adjoining it, thus affording the greatest rigidity and strength. Long through bolts anchored in the bedplate and which extend to the top of the cylinders tie the bedplate, frames, and cylinders together vertically.

The total length of the crankshaft is 57 ft. 6 in. It is made in four sections and bolted together. One section has two cranks for the scavenging pumps and air compressor, there are two sections of three throws each for the six power cylinders, and the fourth section is the generator shaft. Mounted on the shaft between the two power-cylinder sections is the spiral gear which drives the vertical shaft, which in turn drives the camshaft. The two sections for the power cylinders are built up of U-shaped forgings and straight pieces pressed together and assembled by a special method long used by the builder.

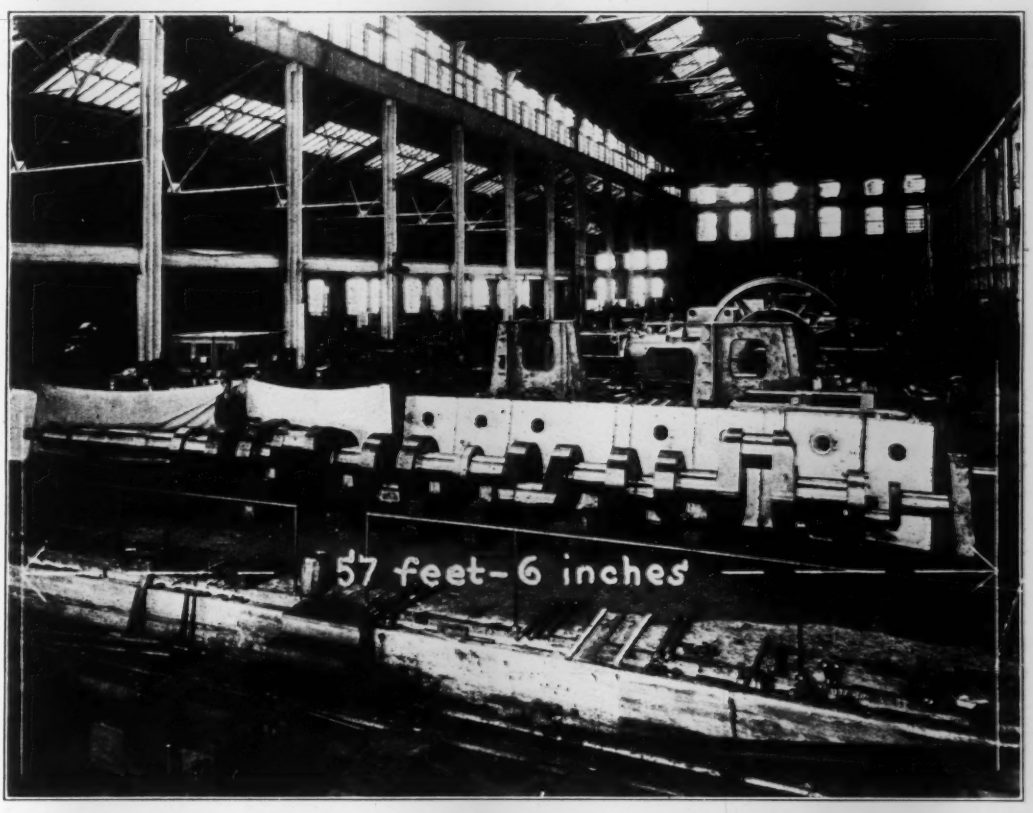


FIG. 5 VIEW OF CRANKSHAFT

The engine is started and controlled from the overhead platform. Air at about 1000 lb. pressure is delivered by the compressor to the four air bottles with which each engine is equipped, three large bottles for starting and a smaller one for injection air.

Each cylinder has its own fuel pump, these being located overhead convenient for inspection and care. A constant volume is discharged at each plunger stroke, but the amount delivered to the fuel-injection valve is regulated by the suction valve forming a bypass valve that is opened sooner or closed later, depending upon the load and the amount of fuel required. The governor is also located overhead. The camshaft is placed in a horizontal position at the top of the engine and actuates the scavenging-, fuel- and starting-valve rocker arms direct from the cams.

LUBRICATION

All parts requiring lubrication are cared for by two systems, mechanical force feed and circulating pressure. The first-mentioned system is for the power and air-compressor cylinders. The pressure system is for all other parts such as the main and crankpin bearings, crossheads, camshaft, gears, etc. After passing through the various bearings, the oil drains into the bedplate where it is taken by a centrifugal pump, forced through a duplex strainer, and then into a storage tank where it is held under pressure. Before being again returned to the engine it is passed through a cooler, which maintains a constant oil temperature. Lubrication for the main and crankpin bearings, crosshead pins, and slides is first delivered to the main bearings and then by means of a system of grooves and drilled passages is carried to crankpins and crossheads. The piping of the pressure system is so arranged that the oil can be cleaned by centrifuging, either continuously or periodically in batches as may be desired.

UTILIZING HEAVY FUEL

These engines must operate on a low-grade fuel oil known as "Bunker C," which is ordinarily carried in supply at the Canal. The characteristics of this fuel are as follows:

Flash point, not lower than 150 deg. fahr.
Viscosity, not greater than 300 sec. at 122 deg. fahr. or 1100 sec. at 86 deg. fahr.
Water and sediment, not greater than 2 per cent.

It will be seen that such a fuel permits of wide variation, as no mention is made of its specific gravity, heating value, or restriction as to sulphur content. At times it is known to be heavy as 16 deg. B. In order that such a heavy fuel may be passed through the fuel pumps, atomizers, etc., even at ordinary room temperatures, special heating appliances must be provided. To keep the fuel heated until utilized, three heaters are used. The oil is obtained from the Balboa oil farm and pumped to a storage tank located on a hill at the rear of the power plant. It then flows by gravity to the basement and passes through a coil immersed in a water bath which is heated by thirty 1000-watt heaters. It is first heated in order that water and solid foreign matter may be more readily removed by the centrifuges. The temperature of these heaters is automatically controlled by a thermostat. After leaving the centrifuges the oil is discharged into a service tank having a float control to maintain a constant fuel supply at the engine. This tank is also provided with a heating coil to raise the temperature of the fuel higher if desired. A motor-driven pump then transfers the fuel into a small supply tank located on the overhead platform of the engine. This tank also has a heating coil, thus keeping the fuel heated until it is delivered to the fuel valves. Hot water discharged from the exhaust manifold is used as the heating element in the last two heaters. Means are provided for regulating the amount of water passing through the coils, thereby maintaining a temperature best suited for any particular fuel.

Scavenging and Cooling

The engine is of the valve-in-head scavenging type. The scavenging air is delivered at a pressure of approximately $4\frac{1}{2}$ to 5 lb. into the scavenging manifold or header which extends practically the full length of the engine. The upper side of the manifold is flat and serves as one side of the overhead platform. Elbows connect this manifold to the heads.

Scavenging air is admitted to the cylinders through four poppet-type scavenging valves placed symmetrically in the heads and opened in unison by rocker arms actuated from the camshaft. With this arrangement a large volume of scavenging air enters the top of the cylinder, and thoroughly expels the exhaust gases through the row of exhaust ports at the bottom. These ports extend entirely around the circumference of the liner and are uncovered by the piston when nearing the end of the stroke. The volume of air admitted is greatly in excess of the cylinder volume, thus completely expelling all the gases and leaving the cylinder filled with the clean air so essential for good Diesel performance.

All the air used for scavenging and fuel injection for each engine is filtered before going to the scavenging pumps and air compressor. A battery of thirty filter sections is placed in the duct taking air from outside the building, while four are placed in the tunnel taking air from below the generator and serve to ventilate the lower half of the generator.

The main cooling-water supply is taken from Gatun Lake through a 20-in. main connecting with a header running the full length of the basement. In order to prevent silt and marine growths

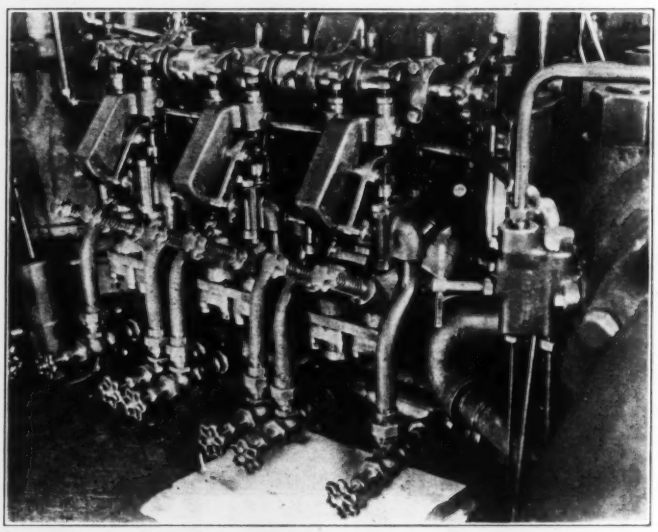


FIG. 7 FUEL PUMPS

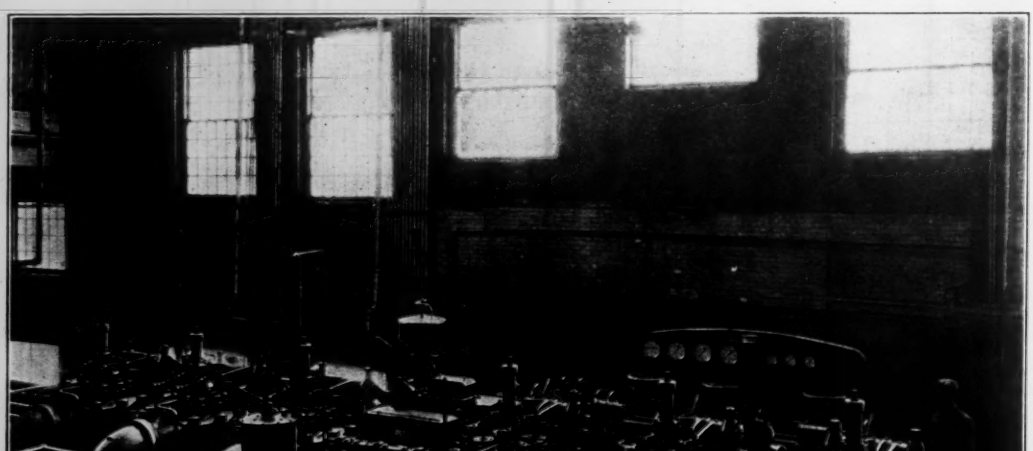


FIG. 6 VIEW OF THE UPPER PLATFORM SHOWING LOCATION OF GAGE BOARD AND AIR BOTTLES, FROM WHICH POINT THE ENGINE IS STARTED AND CONTROLLED

FIG. 8 CONNECTING ROD WITH CRANK AND CROSSHEAD-PIN BEARINGS ATTACHED

getting into the jackets, or clogging other parts of the cooling system, the water is filtered through several layers of sponges. These are known as "Luffa" sponges, a gourd-like vegetable growth common in that locality and prepared for use by taking off the rind, removing the seeds, and curing the remaining fibrous material. The pressure in the header being insufficient to force the water through the jackets, a motor-driven centrifugal pump in the basement is used to secure the required head.

An auxiliary water supply is also provided in case the main supply should fail.

In addition to the usual water jackets of cylinders, heads, air compressor, crosshead guides, and exhaust manifold, the power pistons are also water-cooled. The design of the piston-cooling arrangement is the same as is used with all large Nordberg Diesels. This consists of two sets of swinging arms, one set attached to either side of the crosshead. One set brings the cool water into the hollow crosshead pin, from where it is carried through the hollow piston rod to the uppermost part of the piston. After circulating through the piston head, the water then passes down through a tube outside the piston rod and out into another set of swinging arms attached to the opposite side of the crosshead. The water in its travel cools both the piston and crosshead.

This piston-cooling arrangement is superior to telescoping tubes because of its ready accessibility, ease with which packing can be kept tight, and freedom from leakage. General freedom from all leakage and mechanical trouble is effected by the provision of lubricated bearings to handle mechanical stresses at the joints.

Automatic Devices

With Diesel engines an adequate and dependable supply of cooling water and lubrication must be available at all times. A failure of either for any length of time may result in serious consequences. To guard against damage should either fail, provision is made to shut the engine down quickly by the installation of suitable automatic devices. Should the pressure on the cooling water or that of the oil in the pressure system drop below normal, the fuel to the cylinders is cut off and the engine automatically stopped. Trials showed that when carrying full load this was accomplished in 27 sec., and in 100 sec. on no load.

Each engine with its generator constitutes a separate and complete operating unit including the following auxiliary equipment:

1 Fuel-oil service tank with heating coil
1 Fuel-oil supply tank with heating coil on platform
1 Fuel-oil heater to main centrifuge
1 Type No. 6 Sharples centrifuge for fuel oil (Presurtite)
1 Pump unit consisting of a 1300-g.p.m. centrifugal circulating-water pump, a 75-r.p.m. rotary lubricating-oil pump, and a 9-g.p.m. rotary fuel-oil service pump, all mounted on a common baseplate and driven by a 40-hp. motor
1 Lubricating-oil 2½-in. duplex strainer
1 Lubricating-oil heater
1 Type No. 4 Sharples centrifuge for lubricating oil (open type)
1 Lubricating-oil cooler
1 Lubricating-oil pressure tank
1 Blast-air bottle
3 Starting bottles
Tachometer, pyrometers, thermometers, gages and other instruments conveniently located where needed. Remote electrical control for all auxiliaries.

The following are some of the principal engine dimensions and weights:

Overall length, engine only	48 ft. 6 in.
Overall length, engine and generator complete	61 ft. 6 in.
Width of bedplate	11 ft. 0 in.
Height of engine above floor	21 ft. 0 in.
Overall width	16 ft. 3 in.
Main bearing, diameter	19 in.
Crankpin bearing, diameter	19½ in.
Crosshead-pin bearing, diameter	12 in.
Weight of engine only	815,000 lb.
Weight of engine and generator	1,000,000 lb.
Weight of crankshaft	90,000 lb.

Test Data

The complete testing of these engines before shipment was in itself a very extensive undertaking, involving the construction of a foundation similar to that on which the engine-generator units complete will be mounted in the power plant at the Canal. Because of the cost and space required only one such foundation was considered feasible at the builder's works, so it was necessary to erect, test, dis-assemble, and ship one unit at a time before erection of the subsequent units could proceed. Because of the fact that these engines are the largest Diesel units ever constructed in America, it is believed that the test results will be of interest to the engineering profession in general, and particularly to those who are interested in the economical generation of power. It is worthy of note that in spite of their unusual size, all three engines passed their required acceptance test without serious trouble, easily surpassing the contract guarantees in every respect. It is but natural that with a new design and with a unit of this size some minor corrections will be required. The only disturbing feature which developed was during the preliminary running of the first engine, when it was noticed that the engine was subject to a slight torsional vibration at a speed of approximately 138 r.p.m. This was so close to the designed speed of 125 r.p.m. that it was decided to eliminate the possibility of running into the critical when changing loads by making a change in the shaft so as to raise this critical to a safe value well above the speed range of the engine. This involved the increase in the size of shaft from the No. 6 cylinder outward, also a change in the generator rotor to accommodate this larger shaft. These changes of course caused considerable delay in the testing of the first unit, but the results were totally satisfactory, the disturbing critical being raised approximately to 165 r.p.m. The second and third engines were built with these changes incorporated, and as a result they operated satisfactorily from the start.

The loading of the generators was accomplished by means of a large water rheostat receiving current directly from the generator at 2200 volts and arranged to provide accurate load balance between the three phases by individual adjustment of the plates. The same procedure was followed in the test of the three engines, involving a continuous operating test period of 20 hours subdivided as follows:

2 hours at no load	5 hours at 75 per cent load
3 hours at 25 per cent load	5 hours at 100 per cent load
4 hours at 50 per cent load	1 hour at 110 per cent load

Intervals of 30 to 45 minutes were required between the various load periods for adjustment of the load and to permit the various temperatures and pressures to acquire a fairly stable value, so that the actual continuous operating period was approximately 24 hours.

During the test runs, necessary temperature and pressure readings were taken every ten minutes. Water meters were installed in the several cooling-water branch lines in order to determine accurately the distribution of total supply to the various points, quantity readings being taken every ten minutes. Exhaust-gas temperatures were indicated by a pyrometer with a thermocouple at each cylinder exhaust outlet. Indicator cards of power cylinders were taken every 15 minutes, while cards of compressor and scavenging pumps were taken every 30 minutes. Fuel oil was measured continuously by batch weighing, so that all oil used by the engine throughout the test period was included in the readings taken, and figures hereinafter recorded represent an average value for the test period. An exhaust-gas analysis for each load period was made with a standard Orsat apparatus. The motor-driven circulating water pump, lubricating-oil pump, fuel-oil service pump, and centrifuges consumed approximately 43 kw., this power being charged against the engine in all test-result computations.

Table 1 is taken from one of the Government acceptance tests and is representative of all three engines.

A comparison of the fuel-consumption guarantee with the actual consumption as determined by the test will be of interest. These are shown in Figs. 9 and 10, plotted with reference to horsepower and kilowatts, respectively. It will be noted that the test figures are substantially lower than those guaranteed.

Of the many features that have gained prominence for the Diesel engine, especially among those seeking a dependable and economical form of power unit, the outstanding one is its high thermal efficiency. No other type of prime mover in which power is derived from fuel can equal or even approach it. The heat-balance chart, Fig. 11, shows the effective work derived in comparison with that contained in the fuel in form of heat, also that consumed in

friction and carried away by the cooling water, exhaust gases, and radiation.

The mechanical efficiency from no load to 10 per cent overload can be seen by noting Fig. 12. The area above the curve is lost in friction and consumed by the auxiliaries, compressor, and scavenging pump.

Those associated with the production of power, whether in central stations or isolated power plants, are especially concerned in the number of horsepower- or kilowatt-hours that can be obtained from a given amount of fuel. While these engines are considered larger in size for Diesels, they nevertheless are small in comparison with the generating units found in the large central station of today. If a comparison is made on fuel costs, however, this is decidedly in favor of the Diesel. When operating at full load these engines for the Panama Canal delivered to the switchboard a kilowatt-

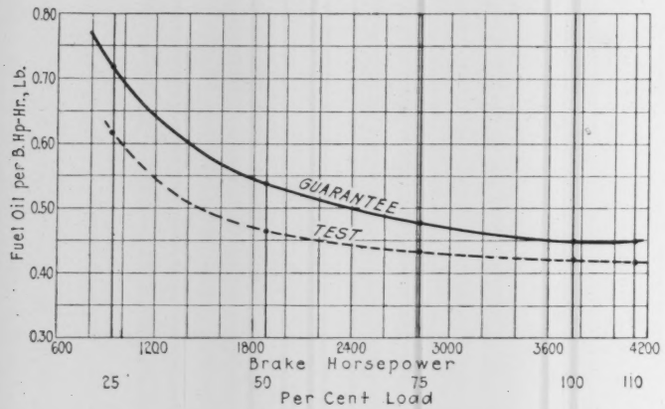


FIG. 9 CHART SHOWING FUEL CONSUMPTION IN POUNDS PER HORSEPOWER-HOUR

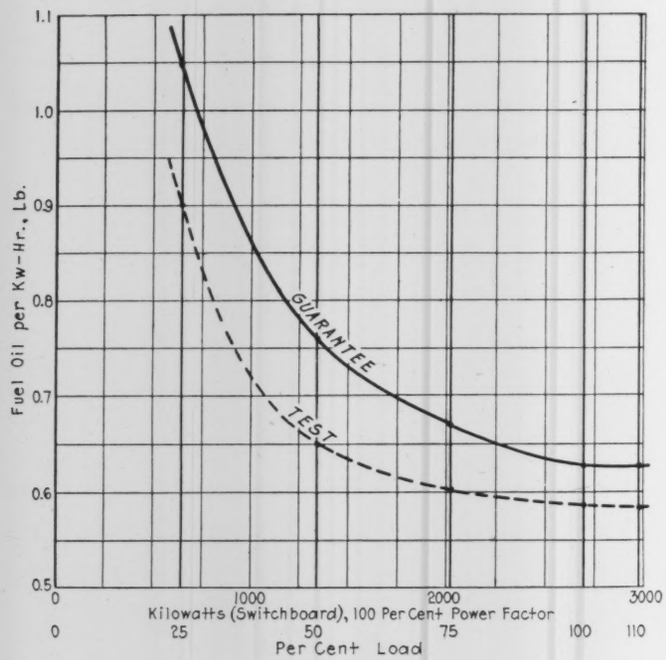


FIG. 10 CHART SHOWING FUEL CONSUMPTION IN POUNDS PER KILOWATT-HOUR

(NOTE: All auxiliary and exciter losses are charged to engine.)

hour on 11,000 B.t.u. or 13.4 kw. per gallon of fuel. On loads less than full, the remarkable economy is even more pronounced. The extremely flat economy curve shows a fairly high economy even at half-load. At this point it only required 12,200 B.t.u. to produce a kilowatt-hour, or 12.2 kilowatt-hours to the gallon. After several months of service in the field and with the running friction reduced, it is but natural to assume that better fuel consumptions will be secured than were recorded in these tests.

There is every reason to believe that the future of the Diesel engine is bright, particularly in the larger sizes. Its dependability

TABLE 1 DATA FROM GOVERNMENT ACCEPTANCE TESTS

Per cent of full load	25	50	75	100	110
Duration of test, min.	180	240	300	300	60
Barometer, in. Hg.	29.79	29.79	29.79	29.79	29.79
Pressures, lb. per sq. in.:					
Injection air	823.0	974.0	1030.0	1070.0	1075.0
Cooling water	38.8	38.8	39.1	39.0	39.0
Lubricating oil	19.3	19.2	18.5	17.9	18.5
Scavenging air	5.16	4.9	5.0	5.0	5.1
Temperatures, deg. fahr.					
Atmosphere	76.0	81.9	80.5	79.0	75.4
Cooling water inlet	64.0	61.9	58.0	57.0	56.0
Jacket outlet	128.4	127.5	129.1	134.8	134.7
Piston cooling outlet	124.2	126.3	127.4	127.6	129.3
Lubricating oil to engine	84.2	85.7	84.1	83.0	82.0
Lubricating oil from engine	99.5	101.5	102.1	103.0	103.4
Exhaust	315	400	510	640	690
High heating value of fuel, B.t.u. per lb.	18,738	18,738	18,738	18,738	18,738
Baumé gravity of fuel at 60 deg. fahr.	20.6	20.6	20.6	20.6	20.6
Viscosity at 122 deg. fahr., sec.	47	47	47	47	47
Viscosity at 86 deg. fahr., sec.	180	180	180	180	180
Sulphur content	1.09	1.09	1.09	1.09	1.09
Fuel oil:					
Lb. per hr.	584.0	871.0	1218.8	1585.6	1728.0
Lb. per i.hp-hr	0.282	0.277	0.309	0.322	0.322
Lb. per b.hp-hr	0.618	0.462	0.431	0.422	0.417
I.hp. of power cylinders	2063.0	3150.0	3945.0	4925.0	5360.0
I.hp. of air compressor	171.6	212.4	236.3	250.2	249.9
I.hp. of scavenging pump	387.5	385.0	376.2	386.0	395.0
B.hp.	943.0	1886.4	2823.0	3759.0	4143.1
Mean indicated pressure, lb. per sq. in.	37.28	57.1	71.45	89.57	97.4
Mean effective pressure, lb. per sq. in.	17.08	34.2	51.2	68.2	75.1
Mechanical efficiency, per cent	45.8	59.9	71.6	76.3	77.2
Thermal efficiency, per cent	21.9	29.4	31.5	32.2	32.6
Speed, r.p.m.	125.65	125.1	125.17	124.71	125.0
Lubricating oil:					
Gallons to power cylinders per 24 hr.					1.5
Gallons to scavenging pump and compressor per 24 hr.					0.5
Average amount circulated through remainder of system, main bearings, crosshead, etc., gal. per hr.					1420

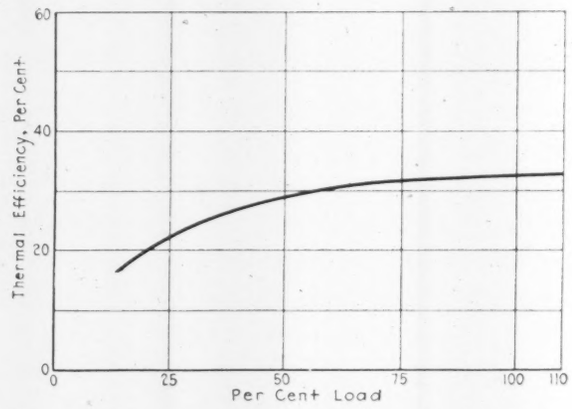


FIG. 11 HEAT BALANCE SHOWING THERMAL EFFICIENCY

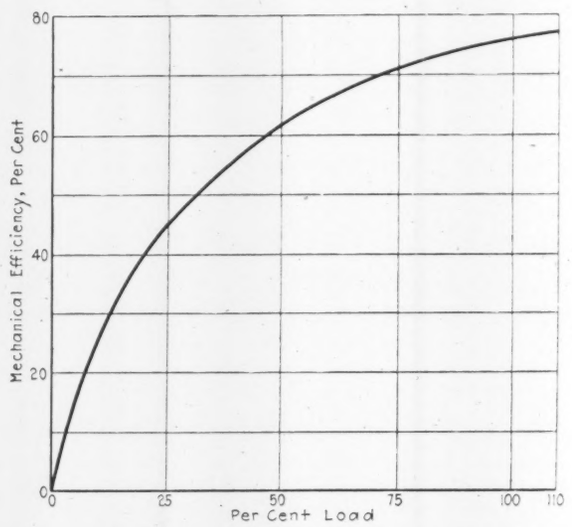


FIG. 12 POWER BALANCE SHOWING MECHANICAL EFFICIENCY

and superior efficiency are no longer questioned. Its wide application is being recognized by all lines of industry and especially in the central-station field. Since the order for these three large engines was placed, the Nordberg Company has also secured orders for two plants of 4500 and 6750 hp. capacity, respectively.

Recent Developments in the Rolling of Sheet Steel

Particulars Regarding the Process of Rolling Steel Sheets—Application of the Continuous Principle to Sheet Rolling, and the Increased Production and Savings Possible Through Its Adoption

MECHANICAL engineers are such large users of sheet steel that any material developments in the art of making it become of interest to them, particularly when these developments are of a really significant character. This is the situation at present in steel-sheet rolling. The art, which has undergone comparatively little modification in the last fifty years, is now passing through a development which is nothing less than revolutionary. Not only the mechanical methods of making sheet but the entire economic structure of this vast industry is being pounded to pieces and reshaped in a new manner, which will probably leave it ultimately entirely different from what it was only two or three years ago. The password to the secret of these striking changes is "continuous rolling."

Continuous Rolling First Used on Wire Rod

The principle of continuous rolling is a very old one. Wire rod was probably the first product which was so rolled, its length being so great and its size so small that it would have been impossible to roll wire rod in return mills without reheating between passes, and such reheating, even if practicable, would increase the cost of the material inordinately. Because of this, from the earliest days in wire-rod rolling the glowing, snakelike rod as it came out of one pass was picked up and returned through another in such a manner that the rod might have been considered as going through several passes at the same time.

The early arrangements for doing this were, of course, very crude—a man, often a boy, with a pair of tongs catching the rod as it came from one pass, and running up to the next roll and inserting it in another pass. In addition the work was extremely dangerous, as a man could easily miss catching with his tongs the writhing rod, which might then coil about him or pierce his body. Accidents of a very terrible nature were quite frequent, and with the equipment then used were unavoidable. The possibilities of continuous rolling as applied to wire rod were, however, so obviously promising that earnest endeavors were made to improve the machinery. Bedson, Garrett, and finally Morgan developed the continuous rolling of wire rod to a point where enormous outputs per mill were obtained with a high degree of safety for those engaged in the work, and at an economy that could not be excelled by any other method of rod production.

The Morgan continuous mill may be considered as representative of that type. It consists (Fig. 1)[1] of a series of horizontal roll stands arranged one after the other, so that the piece to be rolled enters the first stand and travels in a straight line through the mill to the last stand, where it issues as a finished article, thus making but one pass through each stand of rolls. Of course, as the pieces being rolled in several different stands at the same time are elongated through corresponding reduction of area, it is necessary that the surface speeds of the different sets of rolls be so proportioned that each set will travel at a speed as much greater than the preceding one as the lengthening of the piece requires. This is done essentially by a system of driving gears. To care for the wearing down of the rolls they are made adjustable (in billet and rod mills, usually the bottom roll only), and as a further precaution against small irregularities that cannot be overcome by adjustment, each set of rolls is purposely set to run at a slightly greater speed than that required to conform to the speed of the preceding set, so as to keep the rod under tension at all times.

The success of the continuous wire-rod mill led to the application of the same principle to several other types of mills, such as billet mills, sheet-bar mills, and even blooming mills, until finally the conviction grew among rolling-mill engineers that any product could be rolled in a continuous mill provided economic considerations permitted it, the only reservation being made by operating men being the rolling of sheet. Of this more will be said later.

Advantages of Continuous Rolling Process

The matter of economic background for continuous rolling is an important one. The chief advantages of this type of mill are high output and low labor costs. Among the chief disadvantages is the great number of rolls, which not only makes the first cost of the mill very high but adds immensely to the cost of rolls for different sections. For the same reason much time is required for roll changes. Hence the mill is best adapted to roll large amounts of one section continuously, and not at all to the rolling of a very large number of sections, each in comparatively small tonnages.

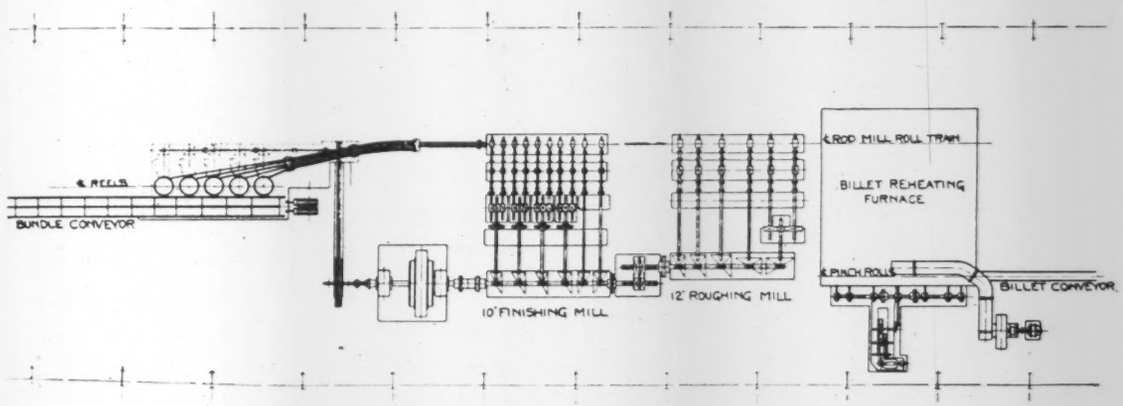


Fig. 1 Plan and Layout of Continuous Rod Mill for 1½-In. Billets

As stated above, whenever a claim was made that continuous rolling could be applied to any material that the economics of the case warranted, it was made with a reservation excluding sheets. There was a reason for this. Quite a number of years ago a bold attempt to roll sheets continuously was made at one of the plants of the American Sheet and Tin Plate Company, a subsidiary of the United States Steel Corporation. The attempt proved to be a dismal failure. Complete particulars of what happened have never been released for publication, but from such information as could be collected it would appear that mechanically the mill was successful to the extent that it did roll sheet in a satisfactory manner. Commercially, however, it was decidedly a failure. Just why this was so is not quite clear and it may have been partly on account of the cost of rolling; more likely, however, it was because this type of mill was built ahead of its time. Continuous mills can be profitable only when a steady and substantial tonnage can be fed into the rolls day in and day out without much changing. A continuous mill is substantially a heavy-tonnage

[1] J. M. Camp and C. B. Francis, The Making, Shaping, and Treating of Steel, 4th ed., fig. 229, p. 838.

producer, and will pay only if used as such. Before the war there was no such tonnage for sheets, and orders ran usually only in lots of a few carloads. It was only the vast development of stamping, metal furniture and automobile manufacture, etc., that gave the big orders on which sheet mills could be run for weeks at a time. At any rate, the American Sheet and Tin Plate Company's continuous sheet mill was not a success, and its failure created a feeling in the trade that the type was not one worth while experimenting with. Moreover, since the cost of a continuous sheet mill may run up to anywhere from $5,000,000 to $7,000,000, it will be easily understood why few companies could get up enough enthusiasm to attack the problem again. Nevertheless there was a steady progress in applying the principle of continuous rolling, and, for example, strip and hoops, which are nothing but narrow sheets, have been rolled continuously for a number of years. The question arises, therefore, why, if sheet 8 in. wide (called hoop) could be rolled continuously, was there such a to-do over the matter of rolling wider material?

This was due to the fact that there are certain things which can be done with short rolls that cannot be done so well with long rolls, and the difference between the rolling of narrow strip and wide sheet lying at the very foundation of the present revolutionary developments is of sufficient importance to warrant devoting a few words to it here in explanation.

Problems Involved in Sheet Rolling

To a layman a steel roll 12 in. in diameter has the appearance of being an enormously rigid structure. Actually, however, when it is subjected to the great forces involved in the rolling of steel and also to the high temperatures encountered therein, the roll undergoes a certain amount of bending distortion which very rapidly increases with the distance between the roll bearings. Furthermore, the power required to roll steel increases roughly with the cubic content of reduction, which, in this case, would mean with the width of the sheet. The size of the bearings naturally increases with the amount of power which has to be handled by the roll, and there must be an obvious relation between the diameter of the roll and the size of the bearing, the former increasing with the latter.

It would appear from the above that if an attempt were made merely to increase the size of a strip mill so as to roll wide sheets, the following situation would be encountered. To take care of the wider sheet a bigger roll would have to be used. The bigger roll would require heavier bearings and greater power. The greater power and heavier bearings would produce a greater tendency toward heating at the bearings. The heat from the bearings would flow into the rolls and expand diametrically the parts nearest the bearings, with the result that instead of a properly flat sheet, one that grew progressively thinner toward the edges would be produced, and because of the great width of the roll there would be also an additional bending tendency which would increase this crowning effect. Furthermore, the ordinary means used to avoid such an occurrence in other forms of rolling, such as giving the rolls an initially convex shape or heating the middle part of the roll with a torch, would be inapplicable, because of the thin gage of the material rolled. These and other considerations have proved to be sufficient to bring about a realization of the fact that a strip mill cannot be converted into a continuous sheet mill by merely increasing the size of the rolls and spreading the bearings apart, and yet conditions in ordinary sheet rolling are such as to make the prospects of continuous rolling extremely attractive from many points of view.

The ordinary sheet mill is probably one of the largest employers of labor in the entire steel industry, and what is more, the labor used in the sheet mill is of a highly skilled, high-priced kind, with an organization unusually well able to enforce its demands. In non-continuous mills sheets are rolled from sheet bars, which are bars from 8 to 12 in. wide and from $1^1/_4$ to $^7/_8$ in. thick, the length of the bar being usually the width of the sheet to be rolled. The ordinary sheet mill is divided into two divisions, the hot mill and the cold mill. The hot mill consists essentially of one or two stands of rolls, furnaces, and a shear. Two stands of rolls are generally used, one stand being known as the roughing or sand mill and the other as the finishing or hot mill. Both stands are of the two-high non-reversing type.

Procedure Followed in Rolling Sheets

The roughing mill is also called the soft mill, because the rolls carry no hardening chill, and is also sometimes referred to as a breakdown mill, a jump mill, or a balanced mill, the last two, however, designating also the type of construction of the roughing mill. Just to indicate the amount of work done in a non-continuous mill, the following is quoted from The Making, Shaping, and Treating of Steel, by J. M. Camp & C. B. Francis, 4th ed., p. 945:

Breaking Down the Bars. The helper deposits the two bars upon the fore plate of the roughing mill, where any loose scale or dirt is removed by a few strokes with a steel brush. With the mill screws adjusted to effect the proper draft, the rougher then immediately grasps one of the bars with his tongs and passes it through the mill, to be grasped with tongs by the catcher on the opposite side of the mill. Then while the catcher is elevating the bar, using the billy for leverage to return it over the top roll, the rougher feeds the second bar into the mill and grasps the first, which the catcher is now steadying on the top roll for the second pass. As the screws are quickly adjusted, this pass is made at once. These movements are made in rapid succession until the bars have been roughed down to the gage that can be taken by the finishing mill. From this point the manner of completing the roughing is adapted to the gage of the sheets. On the finishing mill, the pairs are handled in the same way as they were on the roughing mill for a number of passes until the single pieces are about $^3/_{32}$ in. thick. The two roughed-down bars are then matched, that is, placed one upon the other, and rolled for the last two or three roughing passes. After roughing down, these sheets must be parted, a result that is accomplished by grasping one corner of the top sheet with tongs and pulling upward while the bottom sheet is held down with the foot. As a rule, the roughing down is continued until the bars have been elongated to one-half the length of the sheet desired, or to a gage that gives a weight per square foot twice or four times that of the finished sheets. Sheets heavier than 16 gage are generally finished at once without reheating, but all sheets of lighter gage must be reheated to complete the rolling.

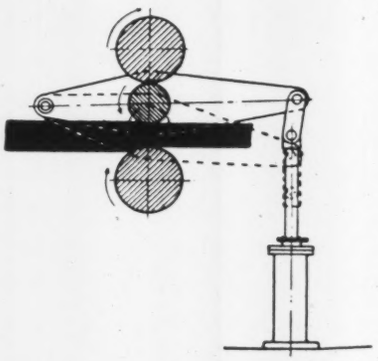


FIG. 2 LAUTH'S MILL

Next comes hot rolling proper. Sheets 13 gage and heavier are rolled singly or one at a time, while sheets lighter than 13 gage are finished in packs of two or more. This is called "doubling," and for a long time was done by hand. The roller turned that end of the sheet which he held in his tongs over the other end and laying his foot on the folded sheet to prevent its springing back, grasped the two ends at once with his tongs and thrust the fold into a doubling machine. This consisted of a pair of flat surfaces whose action was that of a pair of shears with very blunt edges falling flat on instead of passing by each other. The doubled sheet was then reheated and rolled out as if it were a single sheet. The sheets thinner than doubles were produced by folding this doubled sheet a second time, four thicknesses being passed through the rolls at once. Then again when sheets reached a certain size they were simply laid one over the other and rolled as in the case of a single sheet, this being known as packing or matching. Of late in the United States mechanical doublers have been developed and found extensive application. Nevertheless it is easy to realize what a tremendous consumption of labor all these operations involve, especially when due consideration is taken of the fact that each sheet which requires so much work in the way of handling, represents only very small tonnage by way of weight.

The whole process of sheet manufacture was contrary to the American principle of employing as much machinery as possible and as little labor as possible per ton of goods. Mechanical manipulators had everywhere taken the place of hand labor, except in the sheet business. The result was that, compared with other departments of the great steel industry, the output of steel mills was low, the labor consumption high, and the cost of production correspondingly elevated. The answer to the problem of devising an effective method of continuous rolling lay primarily in just two things, the four-high mill and roller bearings. The idea of the four-high mill goes back to the Lauth mill (Fig. 2).[2] B. C. Lauth,

[2] Harboard & Hall, Metallurgy of Steel, vol. 2, fig. 139, p. 135.

of Pittsburgh, realizing that a smaller roll would do the work more rapidly than a larger one if it only had sufficient strength to withstand the pressure, devised a mill in which a roll of small diameter was supported throughout its length by one of larger diameter. The small center roll in the Lauth mill is generally about two-thirds the diameter of the top and bottom rolls, which serve alternately to support it against the bending stresses set up in it by the plate being rolled, and as the strength of the body of the two rolls of similar length subjected to transverse load varies directly as the cube of their respective diameters, the strength of each large roll is about $3^3/_8$ times that of the supported small roll. The Lauth idea has been since applied in several different ways. Edouard Mathey, a Swiss, is said to carry the idea of using small rolls to the utmost limit. To prevent the springing or bending of the very small working rolls used, which are of hardened steel, he supports them by four much larger rolls whereby the pressure is spread over eight bearings of large diameter, and as the rubbing speed of these is low and the pressure per unit of surface likewise low, the power used is reduced. The Bliss cluster mill is another development of the Lauth idea, and here likewise instead of one supporting roll, several are used.

The four-high mill goes a step further, however, than Lauth did, and provides a supporting roll not for one but for both of the working rolls. In this way rolls of strip-rolling sizes may be made strong enough to roll wide sheets without having the power transmitted to the working rolls inordinately increased. The question of heating of bearings to which so much attention had been devoted before was solved very simply by the development of roller bearings of sufficient capacity.

The First Continuous Sheet Mill

When it became clear, as it did theoretically, that both the economic conditions and the state of development of the art were such that the building of a continuous mill was possible, all that was necessary was for some one to find the courage and the money to do it. The Columbia Steel Co., of Elyria, Ohio, was an old company which had recently fallen into the hands of men with a pioneering spirit, engineering ability, and suitable financial connections. They had already put through a development as to the possibility of which there was a good deal of skepticism, namely, the continuous annealing of strip. A little over a year ago they took over the Forged Steel Wheel Co., of Butler, Pa., which up to that time had been a losing proposition financially, secured the necessary capital, and built the first continuous sheet mill in existence. Even before this mill was completed their example was followed by several other companies, and today there are at least four other mills under construction, possibly five, and one or two under very serious consideration. The continuous sheet mill has definitely come to stay, and from all indications there is no longer any serious doubt as to its being a success both technically and commercially. If any doubt now exists it is concerned with the future of non-continuous mills, but that is a matter which will be briefly discussed later.

From what has been said above it will be noticed that while the Columbia Steel Co. was the first to build a successful continuous sheet mill (except, of course, the American Sheet & Tin Plate Co. mill which was dismantled), no new principle is here involved. Because of this, there are no basic patents on continuous sheet mills, and as far as patent protection is concerned, each mill is limited to its ability to cover certain features of operation such as layout, mill drives, shears, etc. There is therefore very great reluctance on the parts of the mills to give out any more information than they can help regarding their installations. This very natural feeling will be thoroughly respected here, and no detail of operation will be described which might in any way be considered as revealing confidential matters; further, the mills described will be designated by letters and not by names.

General Features of Present Continuous-Sheet-Mill Practice

The general features of present practice—which is exclusively American, as no continuous mills have been built abroad—are already sufficiently clear to be stated here. In the first place, a continuous sheet mill can be operated economically only in connection with a steel plant, which means that the ordinary sheet mill working from sheet bar only cannot be converted into a continuous sheet mill without many millions of dollars of additional investment. The second significant feature is that the continuous sheet mill is an outgrowth not of the present sheet mill but of the present strip mill, and as a matter of fact, it is strip-mill and not sheet-mill labor that is usually taken over to run the new mills. The continuous sheet mill cannot use the ordinary thin and narrow sheet bar simply because there is not enough metal in it to produce a long sheet.

The following practice of mill K may give a general idea of the present layout. The start is made in a 27-in. two-high reversing breakdown mill. As a raw material for the start, slabs from 3 to 5 in. thick, of suitable width and a maximum length of 12 ft., are used. In this roughing mill the slab is reduced to a thickness of $^3/_8$ in. and from this it goes to the hot mill, which consists of five stands of four-high mills, and is reduced there to about 16 gage. It should be clearly understood in this connection that the four-high mill to be used for continuous sheet rolling is very different from the ordinary three-high Lauth mill, particularly in that it must be so arranged as to permit a very fine up-and-down adjustment between the rolls. From the hot mill the sheet goes to the cold mill, which consists likewise of a series of four-high stands. There is here a difference in practice, mill K using the universal-mill breakdown end so as to deliver to the hot mill an article of specified width. Mill L, on the other hand, relies on the use of vertical rolls in the first set of continuous rolls to achieve the same effect.

No official figures of production of continuous mills have been given out, and the following data are quoted from statements made by persons not connected with the companies but considered to be reliable. It is stated that at Butler, Pa., 225 tons of sheet $17^1/_2$ in. wide were rolled in an 8-hr. shift, and that on wider sheets an output as high as 1 ton per min. has been attained. This means that a continuous sheet mill can very nearly do in a day what an ordinary mill would be glad to do in a week. There has been an effort to apply the principle of continuous rolling to part of the mill operation so as to obtain some of its benefits without going the full way of the big investment which the new process requires. A mill in the Pittsburgh district specializing in high-grade alloy sheets has therefore hit upon the following scheme. It has now hot mills and will continue to use them, rolling the material down to 11 gage. It proposes to put in four stands of four-high mills of the type used in continuous rolling and expects to reduce the gage from 11 to 24. The interesting feature about this mill is, however, that very long sheets are neither required nor desirable for the purpose for which the particular product rolled by that mill is intended. The maximum length of the sheets is therefore only about 15 ft. and the stands are to be spaced 20 ft. apart, so that the sheet in rolling will pass directly from stand to stand, but will at no time go through two stands at the same time. We are therefore dealing here with consecutive rather than continuous rolling—in mills, however, designed for continuous rolling.

Savings Possible by Application of Continuous Principle to Sheet Rolling

No reliable statements are available as to the saving in cost made by the application of the continuous principle to sheet rolling, but it is stated that this saving may be as high as $15 per ton, which, assuming that everything works out all right, does not seem to be impossible. If we assume further that continuous mills can regularly maintain their production within the high figures mentioned above, it would appear that *some seven continuous mills could take care of all the sheet rolled today in the United States.* Of course, the continuous mill cannot handle small tonnages or odd sizes, and that much will be always left to the present non-continuous mill. And the non-continuous mills, or at least some of them, are already looking for a means of salvation by rearranging their plants so as to start with a slab, break it down to about 11 gage in a jobbing mill, and finish in a few stands of continuous mill, which will materially cut down the cost of production, eliminate some of the most expensive forms of labor, and hence bring them within competing distance, at least on the smaller lines, of the full continuous mills.

Nevertheless the future of the ordinary non-continuous sheet mill is by no means auspicious.

PRESENT AND FUTURE PROSPECTS OF SHEET-STEEL INDUSTRY

As regards the present economic background of the sheet business, certain features are in favor of and certain against the continuous sheet mill, with the balance probably on the favorable side. The demand for sheets has been steadily increasing, and such moves on the part of the industry as the formation of the American Sheet Trade Extension Committee, are certainly helpful in this direction. The advancement in knowledge of sheet stamping, pressing, etc., is also increasing the range of users of sheet. The new varnishes and lacquers which make sheet-steel articles more durable are expected to be a contributing factor in the same direction, and yet with the demand for sheet steel decidedly on the increase, the profits of mill operators have been low and show no tendency upward. This is ascribed by every one concerned to the intense competition for business among the operators and the very keen ability on the part of the buyers, particularly the larger companies, in turning this competitive condition to their benefit. The state of the industry being thus, there is every reason to believe that the lower prices which the continuous sheet mills are already quoting and at which they can make better profits (assuming that everything works out all right) than the non-continuous mills at their higher prices, will attract the business their way. The tendency toward the so-called hand-to-mouth buying is cited as against the interests of the continuous sheet mills in that it is apt to break up business into parcels which may eventually prove too small for them to handle. So far, however, there does not seem to be any indication of this as seriously affecting the business of the only existing mill of that kind, and there is every reason to believe that with the price attraction, purchasers will be willing to give sufficiently large orders to get the full benefit of the lower quotations. The continuous sheet mills will roll every width between strip and approximately 42 in. and every gage, and are therefore capable of taking care of any market requirements. There is very little doubt, therefore, as to the permanency of this new development. In the United States continuous sheet rolling has come to stay. There is every indication that it will remain essentially an American development. Considering the profound changes which it has created in a great industry and the further fact that no new inventions are really involved in it, it is rather surprising that no continuous sheet mills have been built before. They have, however, come to stay.

Self-Starting Centrifugal Pumps

THE author claims that centrifugal pumps will be able to compete successfully with piston pumps in many cases where the latter are employed today as soon as it becomes possible to make the former self-starting, insensitive to air pockets, and without foot valves. German practice is exclusively described, beginning with the so-called water-ring pump, also known as the Elmo air pump. This is quite well known and need not be described here. The new type shown in Fig. 1 has been developed comparatively recently. Here the air pump is contained in a housing immediately underneath that of the centrifugal pump, the exhaust being shifted to the top. This design has the advantage of always keeping the water-ring pump filled with water and consequently ready for operation even when the pump is stopped. A horizontal type of the same character is also made. As a fire pump the combination of a self-starting centrifugal pump with a water-ring pump offers the advantage that very little time is required for the suction period when starting. Furthermore, such a pump takes care of air pockets. A three-stage fire pump of this kind is described and illustrated in the original article. The J. A. Hilpert Co. of Nuremberg which is building these pumps has also developed a slightly modified type for use in water-ring pump carts. The pressure and suction connection pieces are inclined upward at an angle of 45 deg. Such a pump has the advantage of enabling the water-ring cart to be filled rapidly from open stretches of water by means of the centrifugal pump without the necessity of employing a feed valve.

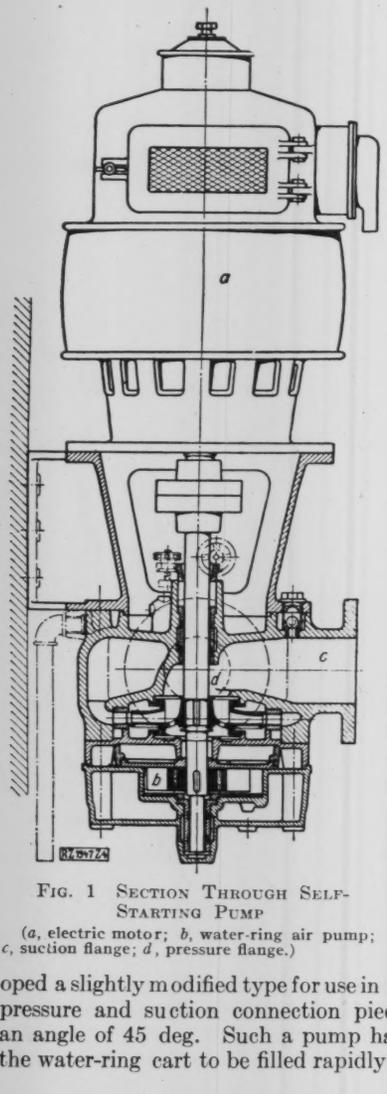


FIG. 1 SECTION THROUGH SELF-STARTING PUMP

(*a*, electric motor; *b*, water-ring air pump; *c*, suction flange; *d*, pressure flange.)

The original article shows a two-stage pump with pipe connections of 175 mm. (6.9 in.) clear diameter as recently supplied for a fire float belonging to the Dantzig fire brigade. This pump has a delivery of 4 cu. m. (880 gal.) per min. at a delivery head of 100 m. (330 ft.) and cannot only be used as fire pump, but is equally useful for bilge pumping or emptying ships. In order to test the suction power, a suction hose measuring about 16 m. (52 ft.) in length was lifted to a height of about 7 m. (23 ft.) above the center of the pump. Even under the most trying conditions the pump began to suck well after a short while, and proved absolutely reliable in every respect.

This type of pump has also found application as a sprinkler pump in stationary fire-extinguishing plants. Contrary to all rules for laying down suction piping, the suction pipe in this case proceeds upward first and then turns downward with 2 bends of 90 deg. each. The arrangement here described is advantageous in so far as it always keeps the pump filled with water and ready for starting.

A peculiarity of water-ring pumps which must be taken into consideration lies in the fact that the vacuum obtainable with the exhausting pump depends on their speed. If a fire pump is driven by a gasoline engine the speed of the pump can be chosen high enough to insure the production of an adequate vacuum in the air pump, even if the rate of delivery of the pump should be small. The matter is different when the pumps are direct-coupled, say, with three-phase a.c. motors, in which case the number of revolutions is predetermined by the frequency. But this drawback does not cause very serious difficulties either, the pump simply being built so as to permit of installing in the air-pump casing that impeller wheel which corresponds to the particular number of revolutions, or the frequency. This does not necessitate the slightest alteration of patterns and can easily be accomplished by merely inserting rings.

The highest vacuum the air pump can attain depends upon the temperature of the water revolving in the air pump. As water of normal temperature is usually delivered, the temperature of the water does not affect the action of the air pump very much. Tests have shown that a geometrical suction head of 8.4 m. (27.5 ft.) can be reached with a water temperature of 40 deg. cent. (104 deg. fahr.) while heads of 7.8 m. and 7.3 m. (25.5 and 24 ft.) are attainable with water temperatures of 50 deg. and 60 deg. cent. (122 deg. and 140 deg. fahr.), respectively. These suction heads are absolutely sufficient for all practical purposes. (Fritz Neumann, Nuremberg, in *Engineering Progress*, vol. 8, no. 2, Feb., 1927, pp. 47–50, 12 figs.)

The Influence of Clearance on the Specific Steam Consumption of Steam Engines and Especially of Locomotives

WHILE in ordinary steam-engine design a consistent effort is made to keep the clearance space in the cylinder as small as possible, say, 7 per cent, in steam-locomotive design very much greater clearances are selected—as high as 20 per cent, in fact. For example, the Northern Railway of Spain in ordering from the German Hanomag Works its 2D1-superheated-steam 4-cylinder compound express locomotives, specified for the high-pressure cylinders a clearance of 20 per cent, and for the low-pressure cylinders, 16 per cent. It would appear from actual experience on the above-mentioned road and the Paris-Orleans Railway that in 4-cylinder compound locomotives notwithstanding the negative set of the valves, extreme compressions occur with ordinary clearance dimensions, and these extreme compressions affect unfavorably the operation of the locomotive, so that by increasing the clearance space a much easier running of the locomotive is obtained. Table 1 gives the clearances of some German-built locomotives and shows how they vary for the various types. The purpose of this article is to determine what influence the amount of clearance has on the specific steam consumption.

TABLE 1 CLEARANCES OF CERTAIN LOCOMOTIVES

		Per cent Crank end	Per cent Head end
German State Railways			
S 10[3]	high pressure	16.3	18.0
	low pressure	20.7	15.6
S 10[2]		10.8	10.5
P 8		12.6	12.8
G 7	high pressure	10.6	9.6
	low pressure	7.3	7.5
G 8[1]		7.0	7.0
G 8[2]		9.9	9.5
G 10		9.7	9.7
G 12		10.4	12.2
T 12		14.1	14.5
T 13		10.0	10.1
T 14		8.8	8.8
T 16		11.4	11.4
T 18		11.8	12.1
Northern Railway of Spain			
2D1—h4v.S.L.	high pressure	20 (average)	
	low pressure	16 (average)	

If, for a given cylinder, one knows the amount of steam needed to fill it and the area of the work diagram for that amount of steam, the ratio of the two will give the specific steam consumption. The work area obtainable for a given amount of steam is of course dependent on a number of circumstances, and particularly (1) on the number of revolutions (wire-drawing loss); (2) the state of the steam, which affects its expansion and compression; (3) the size and design of the cylinder (as it affects heat losses to the wall and leakage losses); (4) admission and exhaust flow; and (5) on the valve-chest pressure.

In the present discussion the author neglects all the factors affecting the specific steam consumption and considers only the influence thereon of the clearance. Because of this he bases his investigation on a theoretical diagram and also makes the assumption that at all cut-offs and all clearances the steam expansion takes place in accordance with the law $pv^{1.15}$ = constant, while the compression occurs according to $pv^{1.2}$ = constant.

The work area and hence the specific steam consumption are, however, also affected by the degree of compression. If the valve setting has been so selected that the compression line at the end reaches exactly the level of the valve-chest pressure, it is not necessary to fill the clearance space with live steam. On the other hand, the actual area of the indicator diagram will be reduced, because of the high compression line.

On the other hand, should there be no compression line whatever at the end condition, the work area would reach its maximum possible dimension. In that case, however, the whole clearance space would have to be filled with steam.

The present investigation was carried out without regard to practical accomplishments, and under the assumption of ideal valve gear operating in such a manner that under the above assumptions the steam diagrams have admissions from 0 to 50 per cent and clearances from 0 to 20 per cent when plotted and measured by planimeter. The compression line is so selected that at the end it is equal to the valve-chest pressure of 13 atmos. abs. (denoted in the present article by $v = 13$), next as equal to only 6 atmos. abs. ($v = 6$), and finally, as equal to 1 at. abs. ($v = 1$, or no compression at all). The specific steam consumption is then determined by the ratio between the work areas determined in the above-described manner and the corresponding quantities of steam required to fill the cylinder. In Figs. 1 and 2 the compression lines have been plotted according to the equation $pv^{1.2}$ = constant for $v = 13$ and $v = 6$, and it is at once apparent how extremely different the lines are made by varying the clearance space ϵ_0.

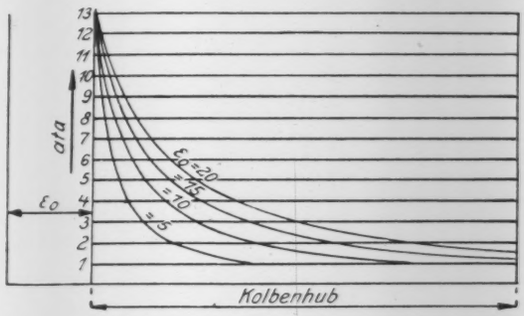


Fig. 1

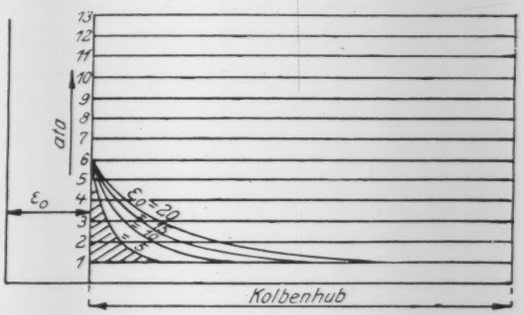


Fig. 2

FIGS. 1 AND 2 CURVES SHOWING VARIATION OF COMPRESSION WITH CLEARANCE

(*ata* = atmospheres absolute; *kolbenhub* = piston stroke.)

Fig. 3 shows the magnitudes of the areas lost from the actual areas of work as compared with $v = 1$ as a result of the compression lines at various degrees of compression; that is, for example, the cross-hatched area in Fig. 2 is produced at $\epsilon_0 = 5$ per cent and a compression of 6 atmos. abs. The area given here is drawn to a length of diagram of 200 mm. (7.87 in.) and pressure ordinates to a scale of 10 mm. (0.394 in.) = 1 atmos. At $\epsilon_0 = 0$ there can be, of course, no compression, as otherwise the final compression pressure would be infinitely great.

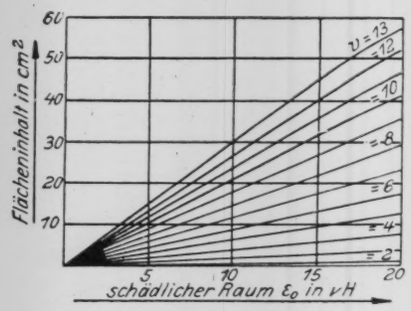


FIG. 3 VARIATION OF INDICATOR DIAGRAM WITH VARIATION IN CLEARANCE
(Ordinates, diagram area in sq. cm.; abscissas, clearance ϵ_0 in per cent.)

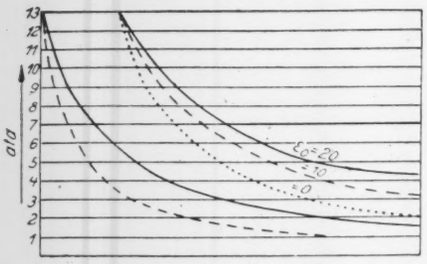


FIG. 4 THEORETICAL STEAM DIAGRAMS FOR GIVEN CONDITIONS OF CLEARANCE AND COMPRESSION WITH 20 PER CENT ADMISSION
(*ata* = atmospheres absolute.)

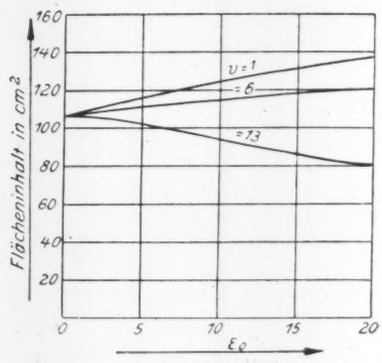


Abb. 5.

FIG. 5 RELATION BETWEEN CLEARANCE AND DEGREE OF COMPRESSION ON ONE HAND AND AREA OF DIAGRAM ON THE OTHER
(20 per cent admission; ordinates, areas of diagram in sq. cm.)

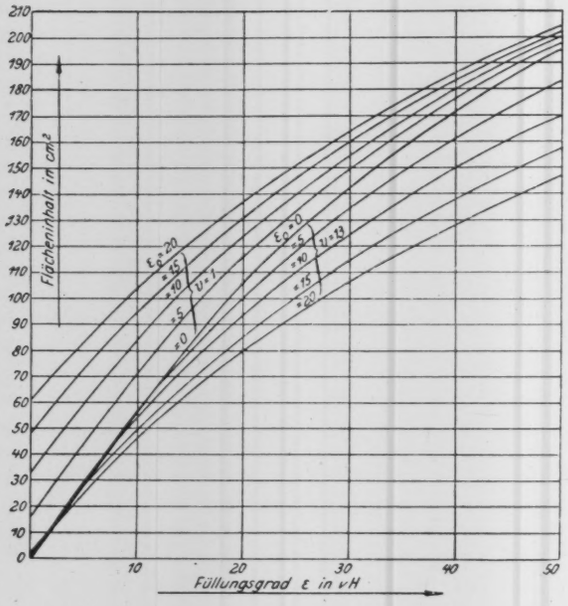


FIG. 6 FUNCTIONAL RELATION BETWEEN ADMISSION AND AREA OF DIAGRAM
(Ordinates, areas of diagram in sq. cm.; abscissas, admission ϵ in per cent.)

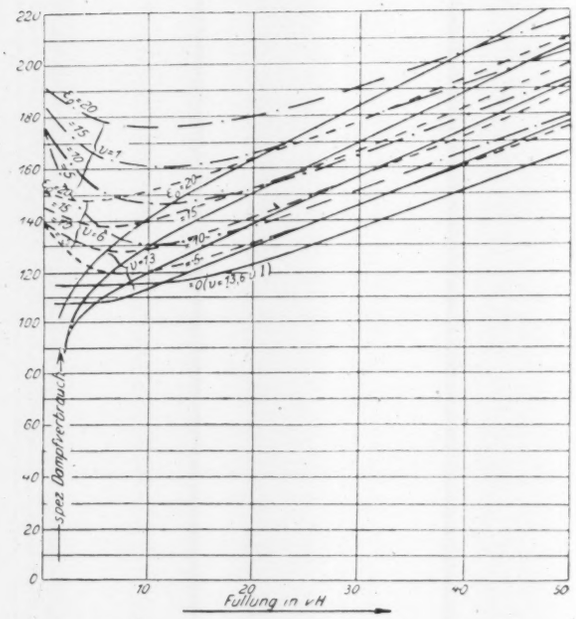
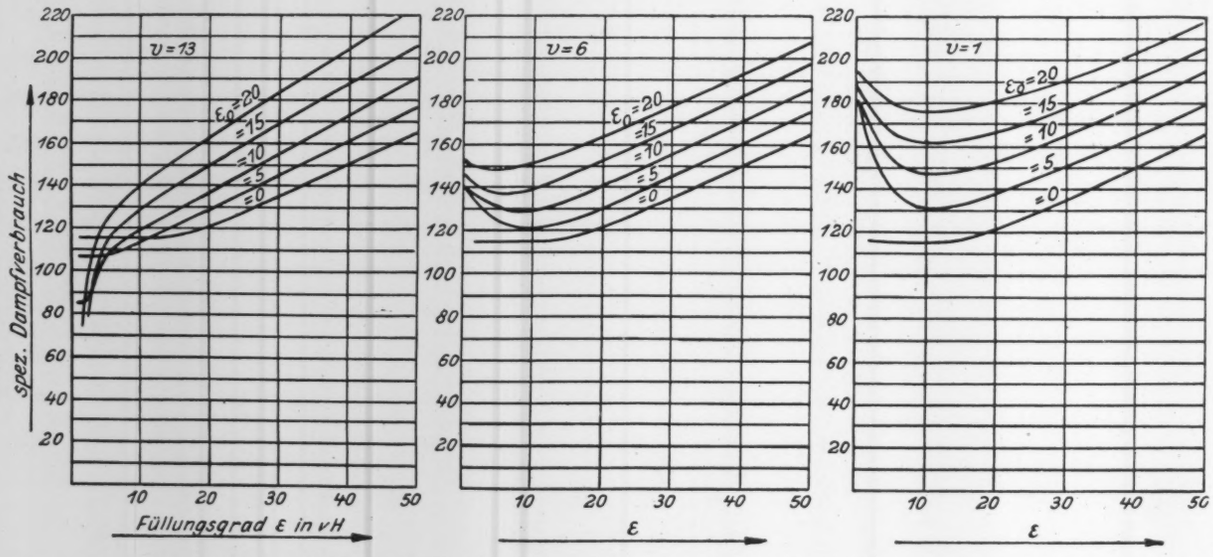


FIG. 10 COMBINATION OF FIGS. 7, 8, AND 9 INTO A SINGLE DIAGRAM
(Ordinates, specific steam consumption; abscissas, admission in per cent.)



FIGS. 7, 8, AND 9 VARIATION OF SPECIFIC STEAM CONSUMPTION WITH ADMISSION AND CLEARANCE
(Ordinates, specific steam consumption; abscissas, admission ϵ in per cent.)

The expansion line varies in a manner similar to that in which the compression line is affected by the variation in the clearance. As an example, Fig. 4 gives a theoretical steam diagram for an admission of $\epsilon = 20$ per cent with $\epsilon_0 = 10$ and 20 per cent and a compression line $v = 13$. As the clearance space increases, both the steam expansion and compression lines become flatter and flatter. The increasing flatness of the expansion line has as a result an increase in the effective area of work, while flattening the compression lines produces an opposite effect. Fig. 5 shows how the clearance space and the degree of compression effect the effective area of the diagram for an admission of 20 per cent. With a compression at 13 atmos. abs. ($v = 13$) the area decreases as ϵ_0 increases, but increases when $v = 6$ and $v = 1$. Fig. 6 gives as functions of degrees of cut-off varying from 0 to 50 per cent the areas for the two terminal cases of degree of compression $v = 1$ and $v = 13$, for ϵ_0 from 0 to 20 per cent, whereas the degrees of compression between $v = 13$ and $v = 1$ can be quickly calculated by subtracting from the areas for $v = 1$ the areas for the various compression lines given in Fig. 3. Thus, for example, according to Fig. 6, the area for $\epsilon = 30$ per cent, $\epsilon_0 = 15$ per cent, and $v = 1$ is 160 sq. cm. (24.8 sq. in.). According to Fig. 3, the area by which the effective area of the diagram is decreased at $\epsilon_0 = 15$ per cent and $v = 6$ per cent is 12.9 sq. cm. (2.0 sq. in.). Hence the area for $\epsilon = 30$ per cent, $\epsilon_0 = 15$ per cent, and $v = 6$ is 160 — 12.9 = 147.1 sq. cm. (22.8 sq. in.). Fig. 6 also indicates that as the admission increases the curves for $v = 1$ run closer and closer. There is no such constancy in the case of curves for $v = 13$, and in the region of lower cut-offs there is intersection between the curves. This lack of regularity for cut-offs of less than 10 per cent is due to the fact that both the compression and expansion of steam take place according to other laws. This would also explain why even when the admission is zero and compression is carried to the valve-chest pressure, there is still theoretically a small area in the diagram available. Since, however, the very small admissions have no particular importance, it is unnecessary to go deeper into the matter.

In order now to determine the specific steam consumption for various circumstances, it is necessary to divide the amount of steam filling the cylinder by the work area obtained in the manner indicated above. It is assumed that we are dealing in each case with a cylinder so selected that its content is 100 liters when 100 per cent full and that it is supplied with dry saturated steam, the residue steam in the cylinder being also dry saturated. It appears, then, from the steam tables that for each 10 per cent of admission, steam to the amount of 0.065 kg. at 13 atmos. abs. is required. In order to bring a 10 per cent clearance space up from 1 atmos. abs. to 13 atmos. abs. or from 6 atmos. abs. to 13 atmos. abs., 0.0338 kg. or 0.0592 kg. is respectively required, so that, for example, with a 20 per cent admission at $\epsilon_0 = 10$ per cent and $v = 6$, there will be required $2 \times 0.065 + 0.0338 = 0.1638$ kg. of steam; the work area obtained in this case according to Fig. 6 is as follows: 124.3 ($v = 1$) — 8.6 ($v = 6$, according to Fig. 3) = 115.7 sq. cm. (17.93 sq. in.). According to these figures the specific steam consumption in this case is a fraction $0.1638/115.7 = 0.001415$ kg. per sq. cm. (0.0201 lb. per sq. in.) of work area.

In the case of an admission of 0 per cent, it is theoretically assumed that the clearance will nevertheless be filled. This calculation is carried through for all circumstances and the results are given in Figs. 7 to 9. As the present investigation does not deal with the absolute magnitude of specific steam consumption per horsepower-hour but only with the variation of the specific steam consumption with the change in clearance and degree of compression, the specific steam consumption may be plotted to any desired scale whatsoever.

If, now, the clearance space $\epsilon_0 = 0$, then for all degrees of compression (from $v = 13$ to $v = 1$) the specific steam consumption will be the same as shown in Figs. 7, 8, and 9. Even though it is practically impossible to make the clearance space equal to 0, this condition is considered here as a limiting case. With an admission of 0 per cent, the specific steam consumption will become infinitely great, since in this case both the work area and the amount of steam required for filling become zero; however, the specific steam consumption attains a finite value at quite a small admission and remains constant up to an admission of about 12 per cent, this being due to the fact that both the work area and the volumes of steam increase in the same ratio. With further increase of admission, because of incomplete steam expansion, the work area does not increase at the same rate as the amount of steam, the result being that beginning with $\epsilon = 12$ per cent the specific steam consumption must increase.

It appears from Fig. 7 that at $v = 13$ as the admission and clearance ϵ_0 increase, the specific steam consumption likewise becomes larger and larger. For example, when the admission is 20 per cent and clearance space 5 per cent the specific steam consumption has a scale value of 122, and at $\epsilon = 20$ per cent, a value of 163. It appears, therefore, that the specific steam consumption has increased 34 per cent with the admission and the final compression pressure remaining constant, but the clearance increasing from 5 to 20 per cent. In the lower admission ranges at $v = 13$ the individual lines of specific steam consumption intersect and with admissions under 10 per cent an increase in clearance space ϵ_0 affects the specific steam consumption favorably. This lack of regularity is explained by the above-mentioned intersection (Fig. 6) of the lines of work areas and need not be considered further, as very low admissions are of no particular importance.

In Fig. 10 are plotted the curves for specific steam consumption for $v = 13$, $v = 6$, and $v = 1$, which means that the curves of Figs. 7, 8, and 9 are combined in a single diagram. This shows clearly the influence of the clearance space and the degree of compression on the specific steam consumption. The variations are greatest in the lower range of admissions, but this is of no importance. Apart from that range it appears that the specific steam consumption increases most with an increase of ϵ and ϵ_0 when $v = 13$, and that a decrease in the degree of compression produces a flattening effect on the curve of specific steam consumption. Thus, for example, with $\epsilon = 20$ and $\epsilon_0 = 20$, the specific steam consumption is the same for $v = 13$ and $v = 6$. When ϵ is increased, however, the specific steam consumption for $v = 13$ mounts so rapidly that at 40 per cent admission it equals the specific steam consumption for $v = 1$, and exceeds it when the admission increases still further. When $\epsilon_0 = 20$ per cent this intersection of the curves is more strongly expressed, and decreases with decreasing ϵ_0 until the curves of steam consumption at $\epsilon_0 = 0$ coincide for $v = 13$, $v = 6$, and $v = 1$.

The specific-steam-consumption curves for all possible cases of admission between 0 and 50 per cent are combined in Fig. 10, and from a consideration of this it would appear that—

1 With the admissions used the specific steam consumption increases with the increase of admission and increase of clearance space.

2 The degree of compression affects the specific steam consumption in such a manner that a higher degree of compression when compared with a lower one produces a decrease of specific steam consumption at the lower admissions and an increased value at higher admissions and vice versa.

Locomotive valve gears are all arranged in such a manner that at smaller admissions a higher degree of compression and at larger admissions a lower degree of compression are produced. The locomotive-valve-gear arrangement therefore affects the specific steam consumption favorably.

The author concludes with a discussion of the effect of varying the clearance space in various locomotives from 7 to 20 per cent. (Dr. of Engrg. Wichtenbahl, Hannover, in *Glasers Annalen*, vol. 100, no. 4/1192, Feb. 15, 1927, pp. 59–62, 12 figs., *tA*)

Short Abstracts of the Month

AERONAUTICS

New Aircraft Engines—Curtiss and Beardmore

THE Curtiss Aeroplane and Motor Company has released the description of its new engines, V-1550 and GV-1550, which have certain essential similarities in design. One of these is water-cooled and the other air-cooled. According to the statement of the author, who is the chief engineer of the Motor Division of

the company to date, there is no question as to the superiority of the performance of water-cooled aircraft engines since they will give a mean effective pressure of 135 lb. per sq. in. at 2300 r.p.m. without supercharging, with a compression ratio of 5.5 to 1 on undoped fuel. This is considerably above the best that the air-cooled engines can do. The reason for the lower m.e.p. at the higher speeds in air-cooled engines is due to the reduction of valve area per cubic inch. This again is due to the use of multiple valves necessitated by conditions of valve cooling. The author believes, therefore, that if a change from water- to air-cooled engines is coming, it will not be sudden but rather gradual.

There are no radical changes in these engines as compared with the previous D-12 type, but several useful refinements. The direct-drive engine developed with high compression a maximum of 708 hp. at 2600 r.p.m. and weighed 725 lb. dry. The geared model weighs 840 lb. dry, which gives an additional weight of 115 lb. due to the gearing. The D-12 engine weighs 680 lb. Therefore, by the addition of 35 lb. in weight it has been possible to increase the power by approximately 150 hp. with a slight reduction in frontal area. This reduction has been possible by the use of spur gears driving the double camshafts, the third spur being placed as an idler below the two gears on the camshafts. The bevel driving gear is mounted on this third gear. This design drops the bevel gear behind the cylinder block, thereby taking off approximately 2 in. of width at the back end of the engine. The engine has a maximum width, as a result of this change, of 26 in., whereas the D-12 is 28 in. wide.

It might be well to point out that a normal engine speed of 2500 r.p.m. is something like 500 r.p.m. higher than that of any air-cooled engine of anywhere near this power. During violent maneuvers in pursuit planes the engine speed in a vertical drive reaches something over 3000 r.p.m. No air-cooled engine of radical form, as far as the author knows, has been made to withstand this severe speed. The advocates of radial engines for pursuit airplanes must face the fact that these high speeds are not as easy to obtain with the heavy crankpin loads as they are in V-type engines with lighter loads. The gasoline engine, particularly with a supercharger, increases its power almost directly in proportion to the engine speed. Therefore, it is very advantageous to use this speed, and the V-type of engine, either water-cooled or air-cooled, undoubtedly has an advantage in this respect. Also, other types of engines which are a compromise between the radial form and the V-form are undoubtedly superior in respect to the heavy crankpin loads than is the radial engine.

The air-cooled radial appears to be the lightest form of engine per horsepower at a given speed. However, it is not the best form as far as head resistance is concerned, owing to its large overall diameter, as has been demonstrated by the comparative performance of the Curtiss Hawk airplane with the Liberty air-cooled V-engine and the Pratt & Whitney Wasp engine of the same power. The machine was faster and the visibility better when using the Liberty air-cooled engine.

By using high engine speeds, which are at present prohibitive in the pure radial type of engine, the water-cooled and air-cooled V-engines can compete with the radial on a basis of weight per horsepower, although at the present time the specific weight is in favor of the air-cooled radial on some of the new engines starting in production, which, however, have not been service tested extensively.

While it has not been definitely proved that the radial form of engine, with its heavy crankpin loadings, cannot be run at such high speeds as 3000 r.p.m. or more, the fact remains that it has not been done.

The Beardmore Typhoon Mark I Engine. The Beardmore Typhoon Mark I engine is a six-cylinder-in-line inverted power plant developing 800 hp. at 1350 r.p.m., and represents a radical departure from the more standard type of aircraft engine. The advantage obtained from the inverted engine, aside from the manner in which it may be accommodated in the nose of a plane, is the greater facility with which gravity feed can be arranged, as the carburetors are automatically placed lower for the same position of crankshaft. As both the exhaust ports and the overhead valve mechanism are situated much farther away from the occupants of the plane, there will also probably be a reduction in the noise.

The Beardmore Typhoon is an attempt to develop the six-cylinder-in-line engine beyond the point long thought possible. It will be appreciated how difficult it is to obtain 800 hp. from six cylinders, but to get that power at a speed as low as 1350 r.p.m. is an achievement. By keeping the cylinders down to six, the number of moving parts is very small, which should help maintenance. The in-line arrangement, which results in an engine of low frontal area, gives a consequent low drag to a plane so equipped.

The ability to develop power at low speeds of revolution is of great importance, particularly in bombers or commercial planes designed for flying normally at cruising speed. Good propeller efficiency can thus be obtained without the complication of gearing.

It is claimed that the combined fuel and oil consumption is 0.46 lb. per hp-hr., which means a reduction in specific weight of a plane equipped with this type of engine. As yet the British Air Ministry will not permit the weight per horsepower to be given, but the figure is said not to be excessive and, for duration flights, the weight is a matter of less importance than the fuel consumption.

Owing to the long stroke, the piston speed in the Typhoon is probably very high, but during the flight of an Avro Aldershot bomber, in which a Typhoon was fitted, on Jan. 24, at Hamble airdrome, England, there was a marked absence of vibration. With the plane standing on the ground and the engine just ticking over, a slight vibration was noticeable, but no more than is usually the case.

The installation of the Typhoon in the Aldershot, while still in the experimental stage, shows that a very clean nose can be obtained in a plane so equipped. The engine is almost totally exposed, but as it tends to keep too cold, it is thought that some cowling and fairing will be tried. (*Aviation*, vol. 22, no. 10, Mar. 7, 1927, Curtiss engine described by Arthur Nutt, Ch. Engr. Motor Div., Curtiss Aeroplane & Motor Co., pp. 465–469, illustrated; Beardmore engine, p. 471, illustrated, *d*)

Air Cooling or Water Cooling for Fighting Planes?

THE present article is based on tests made by the Navy at the Naval Air Station, San Diego. From these tests it would appear that, contrary to somewhat general impressions, the air-cooled plane is exactly equal to the water-cooled machine in horizontal speed with the Wasp turning 1900 r.p.m. and the D-12-M 2200 r.p.m. The air-cooled job gains its top speed much more rapidly in horizontal flight and in power dives. In dead-stick dives the water-cooled machine naturally gains speed more quickly. The air-cooled fighter will outclimb the water-cooled machine, handles easier, and responds to the controls faster. This is due not only to the lighter weight of the air-cooled type, but also to some extent to better balance, with the center of gravity somewhat lower and slightly further aft. On the other hand, the smooth-running water-cooled engine gives less vibration, and this, combined with steadiness due to its greater weight, is conducive to more accurate shooting. The one great disadvantage of the radial air-cooled engine is poor visibility ahead.

The Bureau of Aeronautics at present has on order a number of improved Boeing and Curtiss fighters to be equipped with the Packard-1500 engine. The Packard-1500 develops more power than the D-12-M, but it has, as the author expresses it, "an oil-consumption bug yet to be licked," and it is doubted if it will stand terminal velocity, power dives, and rough handling as cheerfully as the D-12-M does at present. He adds, however, that any engine improves as hard service searches out its defects. The D-12-M has had this experience, while the Packard is just getting it. (F. W. Wead, Lt. Comdr., U. S. N., in *Aviation*, vol. 22, no. 12, Mar. 21, 1927, pp. 565–567, illustrated, *c*)

AIR ENGINEERING (See Heating and Ventilation: Theater Air Cooling)

ENGINEERING MATERIALS

"Italit" Pipe for Water Pressure Piping

"ITALIT" piping has been used for a number of years in Italy, but has only recently been introduced in France. It is made in a manner resembling that used for the manufacture of cardboard

tubing. Around a metal cylinder of a diameter slightly less than the desired piping successive layers are deposited of a dough-like material consisting of cement and asbestos, each layer 0.2 mm. (0.0078 in. thick) until the desired thickness has been obtained. These thin layers superimposed upon each other and powerfully compressed during the process of manufacture unite in a way to form a compact and homogeneous mass. The tubes are said to have an exactly cylindrical form without fins and roughness, and to be very close to desired dimensions. They vary in diameter from 50 mm. to 1 m. (1.96 to 39.37 in.) and the length is 3 m. (9.84 ft.) for the smaller pipe and 4 m. (13.12 ft.) for the larger sizes, the wall thickness varying with the diameter and pressure expected.

Tests made at the various Italian testing laboratories have shown the ability of this piping to resist high hydraulic pressures. Piping 0.19 m. to 0.35 m. (7.4 to 13.77 in.) in diameter and 15 to 29.5 mm. (0.59 to 1.16 in.) wall thickness, broke under pressures varying from 23 to 35 atmos. and that at a time when the process of manufacture had not been perfected to the degree it is now. In 1925 at the Municipal Laboratory of the City of Paris a test was made on a pipe 0.25 m. (9.84 in.) in diameter, 4 m. (13.12 ft.) long, and 32 mm. (1.25 in.) in wall thickness. It stood without breaking or sweating a pressure of 35 atmos.

It is stated that this high resistance is due to the presence of asbestos, the method of manufacture, and, in particular, to the powerful compression mechanically exerted on the successive layers which form the pipe. Tests have shown that pipes so made have a tensile strength nearly three times the average tensile strength of concrete. (*Le Génie Civil*, vol. 90, no. 8, Feb. 19, 1927, p. 200, *d*)

FUELS AND FIRING

Making Rhode Island Coal Usable

THE existence of extensive coal deposits in Rhode Island has been known for over a hundred years. The coal, however, has a high ash content with a low fusing point, which causes clinkering, and also it has a very high density combined with very low volatile content, which retards ignition. It has been stated once that on the day of judgment when the whole world will be aflame, Rhode Island coal will be the last thing to take fire. It is claimed now that these difficulties have been overcome by the application of the Trent process modified for this particular purpose by the Super Fuel Company. In the Trent process oil is added to coal properly pulverized, sticks it and solidifies it, while the ash or dirt is carried off by water. In the modified process the coal is crushed down to small sizes and fed with water to a pulverizer which is charged with 36,000 lb. of cast-iron balls and discharges the coal mixed with water in a finely pulverized condition. It then passes through a classifier which returns the coarse material to the mill for regrinding and sends the material of the proper fineness into an amalgamator. This is simply a large rectangular steel box divided into ten compartments by vertical baffles and having a horizontal shaft running through its entire length with paddles in each compartment. Crude oil is added to the pulverized coal and water at this stage in predetermined proportions and at certain temperatures. In the first compartment of the amalgamator the pulp consisting of pulverized coal, oil, and water appears as a uniformly black mixture, but after being subjected to vigorous agitation as it passes through each compartment, the pulp gradually changes color and is actually a pronounced yellow when it reaches the last compartment. The reason for this is that the carbon and oil have united in the form of tiny balls and the ash has discolored the water which carries it in suspension. The water is then drained off, carrying with it most of the ash and relieving the remaining coal of its objectionable clinkering proclivities. The purified coal and oil which are at this stage in a plastic state like putty, are conveyed to a machine of special design which extrudes it in various streams. A revolving cast-iron wheel with multiple wires clips these streams into any desired length, after which they are automatically delivered into an endless steel conveyor which passes slowly through an oven 200 ft. long. In this oven moisture is driven off and the lighter fractions of the oil are distilled and recovered for subsequent use. Various excellent properties are claimed for the resulting material. It is stated that at the present time the plant has a capacity of 50 tons of finished fuel. (*Combustion*, vol. 16, no. 3, March, 1927, pp. 147–150, 6 figs., *d*)

Study of Cenospheres in the Carbonization of Particles of Coal

THE experiments here described were designed to ascertain the time of exposure required at a definite temperature to modify and destroy the caking properties of coal and to determine whether the destruction of caking properties could be associated more definitely with the evolution of volatile matter and if the two phenomena occurred in a uniform manner. Throughout the investigation the tube used as a furnace was filled with nitrogen, and in the first series of experiments was maintained at a temperature of 400 deg. cent. (752 deg. fahr.)

Tests made at this temperature have shown that no pronounced changes in the rate of destruction of the caking properties could be detected. Apparently the constituents which confer caking properties upon the coal undergo modification or decomposition with certain exceptions in a uniform and gradual manner. At 600 deg. cent. (1112 deg. fahr.), however, the loss of caking power is very rapid, a duration of heating of approximately 3 sec. being sufficient to destroy it completely. An examination of the products showed considerable change had taken place, the particles after carbonization being swollen, rounded, and possessing lustrous surfaces (cenospheres).

The size of the particles of coal has apparently a good deal to do with the decomposition. Particles of 10–30 mesh showed little decomposition not only at 400 but also at 600 deg. cent. (752 and 1112 deg. fahr.). Tests on the alpha, beta, and gamma fractions were also made. The most interesting fact of these is that the cenosphere form could be observed in the product from the carbonization of the gamma fraction and not from the alpha and beta fractions. (Third installment of a serial by H. E. Newall and F. S. Sinnatt in *Fuel in Science and Practice*, vol. 6, no. 3, Mar., 1927, pp. 118–120, 1 fig., *et*)

The "L and N" Process of Coal Distillation

THE following account is based on a statement made at a luncheon in London by Col. Moore-Brabazon, M.P., concerning the Laing and Neilson coal-distillation process, for the development of which it is stated a sum of £125,000, say, $6,000,000, is available.

The "L and N" process is a low-temperature carbonization system, with, however, certain distinctive features. One of the most important relates to oil. Unlike the Bergius process, which aims at the conversion of coal into oils under high pressure, the "L and N" process extracts the oil already existing in the coal, merely leaving the coal oilless and therefore, as the company claims, in an even more satisfactory state, to be burnt than before. Unlike other systems again, the process avoids "cracking" and produces a primary oil from which all the fractions that well oil yields can be derived—gasoline, kerosene, gas oil, Diesel oil, lubricating oil, and phenols in addition. The lubricating oil, for example, as tested by the National Physical Laboratory, is found to be equal to the best lubricating oils on the market, and remembering that all but 2 per cent of the lubricating oils used in this country comes from America, the importance of a new home-produced lubricant is obvious. In addition to about 20 gal. of oil per ton, it is estimated that the process will yield about 14 cwt. of fuel per ton. A large proportion of this is smokeless fuel for burning in an open grate, and it is estimated that an ample market can be found for this at 20 shillings a ton. What is too small to be used in this way is intended for use as pulverized fuel for steam generation. "It has advantages over pulverized coal," Colonel Moore-Brabazon confidently stated, "in this respect in that it is non-explosive, is easier to grind, and burns with a shorter flame. It can be pumped in a pulverized form along pipes into bunkers, behaving in this respect like oil. It can be burnt like fuel oil under boilers, but has the advantage that it gives equal heat results at half the cost of oil. There is a large and increasing demand for its use, and we have no misgivings as to markets open for its consumption." It is not apparently intended to market the gas produced; all this will be utilized in the distillation process itself.

The mechanism of the process is described as comparatively simple. A cylindrical retort, in its present form about 40 ft. long and 4 ft. in diameter, inclined slightly at an angle, rotates slowly. In the higher end is fed coal which slowly travels from one end to the other. This coal is met by a hot gas the temperature of which is controlled and never exceeds the desired temperature. Under the influence of this heat and this flow of gas, the coal yields its oil and gas, but no sooner does the coal give up its oil than the latter passes immediately into a cooler atmosphere than that at which it was liberated. It is swept away by the gas pouring over the coal, and is condensed later and dealt with. It is because the oil once formed is never subjected to a greater heat than what it was released at, that no oil in the process is "cracked." The plant at Barnsley is some 40 ft. long and 4 ft. broad. It is definitely stated that it pays its way, and it is the intention of the new company to build larger installations dealing with 100 tons of coal per day per unit.

Attention is again called to the fact that all the above information is taken from a statement by a party directly and openly interested in the matter. (Editorial in *The Chemical Age*, vol. 16, no. 402, Mar. 12, 1927, pp. 249–250, *d*)

HEATING AND VENTILATION

Theater Air Cooling

THE article is of particular interest because of the scarcity of information on the engineering factors involved in this new art. The object to be obtained in cooling a theater is neither a certain temperature nor a certain humidity, but a purely psychological degree of comfort. It is as bad to overcool a theater as to undercool it. During midsummer the body becomes more or less accustomed to high temperatures and a drop from, say, 90 deg. fahr. outside to 70 deg. inside may be and often is too great a change for comfort. As an experiment the author tried sitting in the balcony with an outside temperature of 90 deg. and the theater temperature of 78 deg., and for the first 20 minutes he felt distinctly chilly.

To hold the temperature of a theater at an even line of comfort the engineer has two unit factors to consider—(*a*) a cubic foot of air and (*b*) the allowable range of temperature of that air. The author gives formulas to determining them and points out the general principle that the greater the supply fans' relative displacement, the less liability there will be to cold drafts. He also gives formulas for calculation of summer heat loss and cubic-foot-per-minute displacement per person, as well as a calculation of the refrigeration required. Among the details of the ventilating scheme the question of stratification of warm and cold air is briefly discussed and a remedy suggested. (S. L. Goodwin, Air Conditioning Engineer, Office of Thos. W. Lamb, New York, in *The Heating and Ventilating Magazine*, vol. 24, no. 3, March, 1927, pp. 61–64 and 71, 1 fig., *pdA*)

True Vapor Heating Defined

THE author shows that the definition of true vapor heating does not depend on such things as piping arrangement, type of radiation, or boiler. All true vapor systems normally operate on a slight vacuum which is self-induced, and not produced by the aid of any power-driven mechanical apparatus. In this they differ from the vacuum system employing a power-operated vacuum pump. As regards vapor-vacuum or vacuum-vapor systems, the combination is a vacuum system pure and simple, where the vacuum is produced by a power-driven apparatus and a simple vapor system where the vacuum is produced by internal condensation. (*The Heating and Ventilating Magazine*, vol. 24, no. 3, March, 1927, p. 87, *g*)

HYDRAULIC ENGINEERING (See also Marine Engineering: The Practical Application of Modern Hydrodynamics to Marine Propulsion)

The New Pelton Wheel Deflection Governor

DESCRIPTION of a balanced deflector patented in England. In Fig. 11 the deflector is shown at full load. The passage in the deflector is parallel to the axis of the jet, and the sharp edges of the deflector just fail to touch the jet. The state of affairs when the load is thrown off is shown in Fig. 12. The jet now impinges on two surfaces, one on the inside and the other on the outside of the deflector. These surfaces are arcs of concentric circles having as their center the axis of rotation at the deflector. The pressure on both surfaces is consequently radial, and the change exerts no turning on the deflector but merely a pressure on the

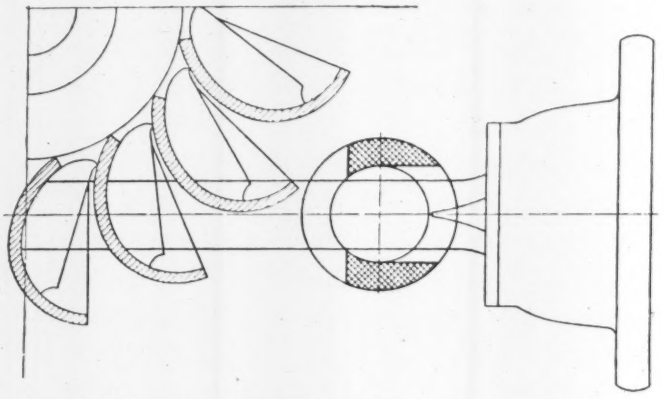


FIG. 11 POSITION OF PITMAN DEFLECTOR AT FULL LOAD

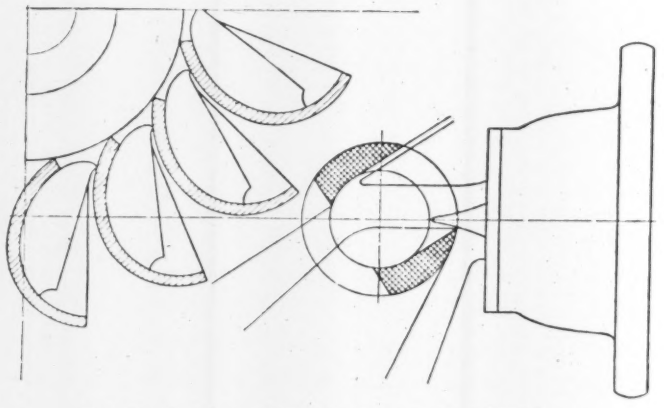


FIG. 12 POSITION OF PITMAN DEFLECTOR AT NO LOAD

deflector bearings. The force to operate the deflector is merely that to overcome friction, and for this the governor is usually sufficient without relay gear. The original article shows how, where economy of water is desired, the governor can be interconnected with the needle valve. The deflector can be fitted to existing motors, or new hydraulic motors can be supplied with this deflector incorporated. (*Mechanical World*, vol. 81, no. 2096, Mar. 4, 1927, p. 160, 3 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See Aeronautics: New Aircraft Engines—Curtiss and Beardmore)

MACHINE TOOLS

An Investigation of Twist Drills

THIS investigation of twist drills is the second of a series which has been planned to determine the factors relating to the design and performance of this widely used production tool. Results of the initial investigation were published in Bulletin No. 103 of the Engineering Experiment Station in 1917. As stated in the preface of that bulletin, the first part of the investigation was essentially preliminary in scope with the object of determining the general characteristics of the twist drill as a cutting tool, and of opening the way for further and more extensive investigations in the phenomena of drilling. The second part, with which the present bulletin is concerned, deals specifically with the relation between helix angle and torque, thrust, and endurance of the drill when drilling in gray cast iron and steel.

During the late European war the original program of tests

was temporarily abandoned, but in 1920 it was revived, and with it plans for an improved testing equipment. A heavy-duty drilling machine was installed and equipped with a dynamometer capable of measuring forces and recording data beyond the capacity of the original apparatus. As the present dynamometer is of novel design, it is described in some detail in the present bulletin. A period of two years has been employed by the authors in obtaining the results herewith presented.

In the initial investigation of twist drills reported in Bulletin No. 103 the fact was disclosed, and, so far as the authors are aware, for the first time, that power consumption at the drill point is influenced more by changes in helix angle than by any other one factor of design. It was found that at heavy drilling rates the power required at the drill point in gray cast iron was reduced more than 20 per cent by increasing the helix angle from 26 deg. to 35 deg. As these tests were conducted on gray iron only, the results were not considered generally applicable until similar tests had been made on the carbon and alloy steels commonly used in industry. The question of drill endurance, especially in drilling steels, was likewise an undetermined matter. It was therefore decided to make a comprehensive study of the relation of the helix angle of twist drills to the power consumption and endurance, in both gray cast iron and steel, with the object of determining what helix angle best satisfies the inseparable requirements of (*a*) economy in the use of power and (*b*) resistance of the cutting edge to wear and destruction.

One-inch high-speed milled drills were used in these tests. Drills of this size can be driven at high rates of speed and feed without liability of breakage. Several drills were used in these tests. They were similar in dimensions except as to helix angles which varied by progressive steps from 15 to 45 deg. The thickness of the web in all drills was made 0.10 in. and was constant from point to shank. The drills were ground by machine in the same manner.

Notwithstanding the wide distribution facilities among manufacturers and the independent character of the industry, twist drills as furnished to the trade are remarkably uniform in appearance and in productive capacity. Without the usual trademarks it would be difficult in a cursory examination to identify the drills of different manufacturers and to distinguish one part from another, and it is doubtful if the usual shop test would show marked differences in their performance. This similarity is only superficial, however, as a careful examination of the commercial points of drills shows many and pronounced variations in design and details of construction. Maximum variations in certain dimensions and properties between drills of various manufacturers are given in a table in the present bulletin.

Generally, helix angles have been increased by makers of twist drills during the period between the initial and the present investigation, but drills are still made with helix angles of 23, 24, and 25 deg. Hand grinding continues to be the prevailing method employed by drill manufacturers for pointing drills, but this practice is no longer universal. To a large extent hardness and durability have been standardized by the employment of high-grade steels and scientific methods of heat treatment. A variation of over 30 per cent in the price of drills in the open market raises questions relating to production and distribution which cannot be considered here, although they are of economic importance to both manufacturer and users of drills.

Summary of Results Obtained

Only a summary of the results of this investigation can be given here because of lack of space.

1 Torque and thrust decreased progressively as the helix angle was increased from 15 to 45 deg.; both were lowest when the helix angle was 45 deg.

2 At the highest rate of feed used, 0.0629 in. per revolution, increasing the helix angle from 15 to 45 deg. resulted in reducing the torque by 25.5 per cent and the thrust by 37.2 per cent.

3 Thrust was influenced most by helix angle, and by the thickness of the web. Test drills with a web thickness of 0.1 in., constant from point to shank, gave entire satisfaction at all speeds and feeds.

4 Savings in power consumption at the drill point by increasing the helix angle from 15 to 45 deg. ranged from 2 to 26 per cent at drilling rates of 0.0165 and 0.0629 in. per revolution, respectively.

5 Chip removal when drilling holes 5 in. deep was effective with drills having constant helix angles from point to shank.

6 From 95 to 99 per cent of the power consumption at the drill point was due to torque, the remainder resulting from thrust.

7 Drill endurance was not influenced by changes in helix angle from 26 to 45 deg., inclusive, at normal drilling rates.

Observations Made During Tests in Steel

The following observations were made during tests in steel:

1 Torque and thrust decreased progressively as the helix angle was increased for all the steels drilled in the test; both were lowest when the helix angle was 45 deg.

2 At the highest rate of feed used, 0.0320 in. per revolution, increasing the helix angle from 15 to 45 deg. resulted in reducing the drill torque by 8.3 per cent in steel having a low machinability factor (medium-carbon steel), and by 31.6 per cent in steel having a high machinability factor (low-carbon nickel steel).

3 For the same drilling rate, increasing the helix angle from 15 to 45 deg. resulted in reducing thrust on the end of the drill by 21.1 per cent in chromium-nickel steel of low machinability, and by 46.8 per cent in low-carbon nickel steel of high machinability.

4 Savings in power consumption at the drill point due to increasing the helix angle from 26 to 45 deg. ranged from 8.5 per cent in steel of low machinability to 31.8 per cent in steel of high machinability at a drilling rate of 0.0320 in. per revolution.

5 Drill endurance was not affected by changes in helix angle from 26 to 45 deg., inclusive, at normal drilling rates, and in steels of low machinability. At the higher drilling rates, in certain carbon and alloy steels, drills with helix angles above 35 deg. or below 28 deg. showed reduced endurance.

Summary of Conclusions

As a result of this investigation the following general conclusions may be drawn:

Power consumption at the drill point in drilling gray cast iron or steel decreases as the helix angle is increased from 15 to 45 deg., the amount of power consumed being lowest in drills with helix angles of 45 deg.

Saving in power consumption at the drill point resulting from the use of the larger helix angles varies with the machinability of the metal and with the drilling rate. This saving at large feeds in steels of high machinability will exceed 30.0 per cent; in steels of low machinability, 8.0 per cent; and in gray cast iron, 25.0 per cent. At lower drilling rates the saving is approximately proportional to the rate of steel.

The torque on the drill and the thrust on the end of the drill decrease progressively as the helix angle is increased from 15 to 45 deg., and both are at a minimum in drills with helix angles of 45 deg.

Considering the principal factors affecting drill design, power consumption at the drill point, and endurance of the cutting edge, drills with helix angles from 32 to 35 deg. give the most satisfactory performance in gray cast iron and steel. Drills with these helix angles are equally efficient in gray cast iron and steels.

There is no apparent justification for reducing the helix angle from point to shank for the purpose of increasing chip space. Chip ejection from deep holes by drills so constructed is not better than by drills with constant helix angles.

A web thickness of 0.10 in., uniform from point to shank, proved adequate in this test for 1-in. high-speed drills having helix angles above 32 deg. For drills of lesser helix angles this web thickness does not give the requisite torsional strength for drilling at high rate of feed in steel.

Drill torque may be taken to be an accurate measure of the machinability of metals. Apparently machinability is a factor which depends upon the combined effect of the hardness and plasticity characteristics of metals, and consequently it is not correctly measured by the Brinell number. (Bruce W. Benedict (Mem. A.S.M.E.) and Albert E. Hershey in *University of Illinois Bulletin*, vol. 24, no. 11, Nov. 16, 1926 (also Bulletin No. 159, Engineering Experiment Station), 74 pp., 28 figs., with extensive bibliography, pp. 59–74, *epA*)

MARINE ENGINEERING

The Practical Application of Modern Hydrodynamics to Marine Propulsion

The present paper deals with the application of modern hydrodynamic theory to the design and analysis of commercial propellers on merchant ships. Modern hydrodynamics differs from the older theory of an ideal fluid chiefly by taking into account the effect of surface conditions. Surface friction as ordinarily understood does not occur because the layer of fluid in immediate contact with the body is at rest relative to it, and the transition from the velocity of the body to that of the fluid takes place in a thin layer of the fluid, the thickness of which depends on the viscosity. Under certain conditions this retardation produces a reversal of flow in the boundary layer, leading to the formation of vortices. Whenever this is the case the theory of non-viscous flow is not applicable without certain modifications.

From this the author proceeds to the determination of functional expressions determining the motion of a fluid, beginning with a non-viscous fluid, and derives the fundamental hydrodynamic equations, as well as equations determining vortex motion. He shows that the dynamic action of the propeller arises from the combination of a stationary two-dimensional flow, which may be regarded as a parallel flow having a velocity for which an expression is given, and which makes a certain angle with the blade element, with circulation around the blade.

The nature of the flow around any blade cross-section is deduced from the well-known flow around a circular cylinder or circular cross-section for uniplanar flow by establishing a conformal relationship between the two by means of the proper coördinating function of the complex variables.

The process by which it is done is somewhat complicated, but it is said that it is possible by using it to determine the pressure distribution for any given blade section, and that calculated results have been found to agree closely with experimental measurements.

Equations are given to indicate the character of the flow at the propeller edges. The flow at the trailing edge is controlled by a proper selection of what the author calls the circulation parameter, while that at the leading edge is taken care of in practice by rounding off the edge. This result based on purely theoretical consideration has been confirmed by experiment in model tanks, where the gain in efficiency due to this source alone has been shown to be in the neighborhood of 1 per cent.

The distribution of pressure in the neighborhood of the blade element is next considered, and it is found that the velocity and therefore the hydrodynamic pressure at points on the propeller symmetrically disposed with respect to the origin have the same value, and furthermore, neither the translatory motion by itself nor the circulatory motion by itself gives rise to any resultant pressure on the blade element. This symmetry, however, does not hold for the resultant velocity compounded of both components. The theory, of which the above represents only a brief abstract, is next applied to actual propellers. Only a very brief abstract of this part is possible because of lack of space.

Since the expressions for thrust and torque still involve an undetermined parameter K_1, which must be found by experiment, these relations may be applied directly to propeller design without any loss in generality. The noteworthy fact is that these relations are rational, and based on sound mathematical and physical principles. Consequently they furnish a true insight into the major facts of propulsion and clear up many facts which have always been obscured by the limitations of empirical methods.

This is followed by an elaboration of dimensional equations for such principal elements of propeller design as diameter, speed, thrust, torque, and density.

By a process described the thrust and torque characteristics have been derived for six types of blade profiles and these characteristics are summarized in a table in the original article.

These formulas differ essentially from so-called propeller characteristics in use heretofore in that they exhibit a complete functional relation between the quantities involved. It has been customary heretofore to form some arbitrary combination of variables involving thrust, and another involving torque, and plot these relations as determined by experiment in terms of slip. The results then appeared in the form of separate curves for each area ratio and each pitch ratio.

In the present case one general formula for thrust and one for torque were established. The functional form of these relations has been determined in two ways entirely independent of each other, namely, by direct analysis, and by the theory of dimensions. The results are therefore physically rigorous as to form and absolutely general in application.

Moreover the fact that the combinations of variables involved are all non-dimensional makes it possible to apply the formulas directly either to small-scale models or to full-scale practice. Furthermore they are not restricted to one particular class of vessels as in the case of empirical formulas, but apply equally well to all speeds and dimensions throughout the entire range of design.

It may be noted, however, that these formulas are not intended to apply to aircraft propellers. The latter are not subject to the same mechanical limitations as marine propellers, and therefore in applying the circulation theory to aircraft propellers we proceed somewhat differently from the method used in what precedes, and derive the required characteristics by applying directly the calculus condition for maximum efficiency. For aircraft propellers it is possible to obtain a more favorable aspect ratio than in the case of marine propellers, together with a very much lighter unit load and smaller angle of incidence, as well as fewer blades and therefore less interference, all of which combine to raise the efficiency above the best attainable in marine practice. (Stephen E. Slocum, Ph.D., in *Journal of the American Society of Naval Engineers*, vol. 39, no. 1, Feb., 1927, pp. 1–38, 5 figs., 2 plates, *mtA*)

MEASURING APPARATUS

The Powbal Fuel Measurer for Oil Engines

The name "Powbal" consists of the first syllables of the two words, "power" and "balancer," it being claimed that by this means the power output of, say, a six-cylinder Diesel engine can be equalized in the various cylinders in a few minutes.

The whole apparatus is smaller than the fuel pumps of an engine immediately above which it is located, this being the best though not the only position.

The apparatus consists of two main parts, one being the bypass-valve box and the other the measuring device which will be attached to either end of the valve box. In the bypass-valve box there is a set of three screw-down valves disposed in a vertical line and controlling the fuel going to one cylinder of the engine. The fuel from the fuel pump enters the valve box and passes through it to the fuel-injection valve of the engine. When it is desired to measure the quantity of the fuel being pumped into any one of the engine cylinders, one upper and one lower valve are open and the middle valve in the same vertical line is shut. This causes the whole of the fuel discharged by the corresponding pump to be bypassed through the measuring device on its way to the engine cylinder. As the middle valve is being closed the apparatus comes into action, and when the valve is lightly seated the exact quantity of fuel in cubic inches and cubic centimeters discharged by each stroke of the pump is clearly indicated by the pointer. The quantity of the fuel may be then regulated if necessary by altering the opening period of the suction valve on the pump. Fig. 13 shows the measuring device which is attached to one end of the bypass-valve box.

To follow its action, assume that all of the internal spaces and passages are completely filled with fuel oil under pressure and that the relative position of the parts is as illustrated.

During the discharge period of the pump the fuel oil enters the lower part of the chamber as indicated by the arrow, and passes through a number of vertical passages into the space A. The increasing amount of fuel oil entering this space causes the sliding cylinder C to rise against the action of the light spring mounted upon it.

At the end of the pump's working stroke, the sliding cylinder remains stationary in a position depending upon the quantity of fuel oil delivered by the pump. Through the medium of simple mechanism the height of the sliding cylinder, or in other words the amount of oil delivered into it, is clearly indicated on a graduated dial.

As the sliding cylinder rises, an amount of oil equal in volume to

that entering the space A is forced through the outlet passage to the engine cylinder so that the timing of the fuel charge entering the fuel-injection valve is not affected in the least by bypassing the fuel through the fuel measurer.

To return the sliding cylinder to its original or lowest position so that it will be ready to measure the next charge of fuel oil de-

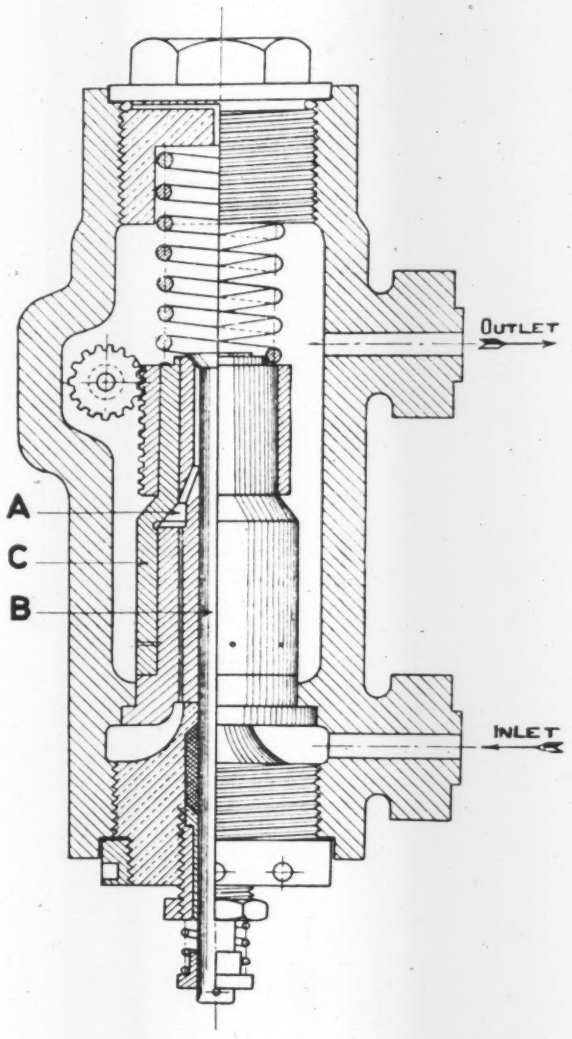


FIG. 13 MEASURING DEVICE OF THE POWBAL FUEL MEASURER FOR OIL ENGINES

livered by the pump, the small central poppet valve B, which is mechanically operated by a simple drive from any moving part of the engine, is opened for a short period during the idle or suction stroke of the fuel pump.

When the sliding cylinder is in an elevated position the fuel oil in the space A is under slightly greater pressure than the fuel in the remainder of the system, amounting to approximately 10 lb. per sq. in., due to the action of the spring mounted on top of the sliding cylinder.

When the central poppet valve opens, the charge of fuel oil delivered into the space A by the previous working stroke of the pump will therefore escape past the valve, or be transferred from the inside to the outside of the sliding cylinder, and the sliding cylinder will return to its original or lowest position ready to receive the next charge delivered by the fuel pump. After the fuel charge has been transferred and before the fuel pump begins discharging again, the central poppet valve reseats.

If desired, a revolving paper drum similar to that provided on pressure indicators can easily be fitted and a continuous diagram obtained showing successive charges delivered by the pump and the action of the governor. The apparatus is so sensitive that even when an engine appears to be working perfectly steady the action of a centrifugal governor upon the pump suction valves can be clearly observed.

Although the apparatus works under a high pressure, i.e., about 1000 lb. per sq. in., yet the difference in pressure between any two spaces in the whole apparatus, or the effective pressure tending to cause leakage of fluid from any one space to any other space is only about 10 lb. per sq. in. Therefore no extra-fine fits are necessary to insure accurate measurement of the fuel charge, and prevention of leakage passed by any of the valves in the bypass-valve box or surfaces in the fuel measurer is an easy matter.

To prevent the possibility of two valves belonging to different cylinders being open to the fuel measurer at the same time, a simple locking device, not shown, is fitted which allows a valve to be opened only after all other valves on the same line are shut. Thus only one valve of the lower row and one valve of the upper row can be open at the same time. (E. Wood in a paper entitled Notes on the Running of Oil Engines and Description of the Powbal Fuel Measurer, in *Transactions of the Institute of Marine Engineers*, Feb., 1927, pp. 53–65, 2 figs., *d*)

MOTOR-CAR ENGINEERING

A Continuously Variable Gear

A NEW continuously variable positive change gear is said to have been brought out in France under the name of the L. C. B. The device uses a gear wheel meshing with the planetary pinion. On the axis of the latter is fulcrumed a lever, the free end of which carries a sliding shoe working in a circular groove. This groove may be made to move in an eccentric position with relation to the gear wheel, and this together with the ratchet device is relied upon to produce the changes of speed. The device is described in considerable detail in the original article and represents a unit taking the place of the present change-gear box on an automobile. (*Automotive Industries*, vol. 56, no. 10, Mar. 12, 1927, pp. 400–401, 4 figs., *d*)

POWER-PLANT ENGINEERING (See also Railroad Engineering: Canadian Pacific Locomotive with Nickel-Steel Boiler)

An Unusual Boiler Explosion

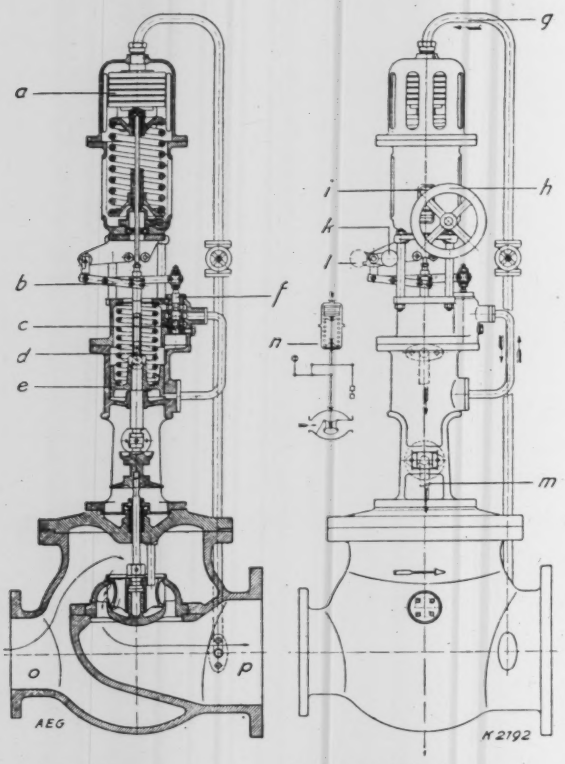
AN INQUIRY made into an explosion of a water-tube boiler in a plant in London would indicate that the explosion was due to an accumulation of sludge in the tubes, in consequence of the water-softening plant being worked beyond its capacity. The boiler was of the usual Babcock & Wilcox land type with two horizontal drums, and a working steam pressure of 200 lb. per sq. in. For some months prior to the explosion the water-softening plant had frequently been used beyond its capacity and insufficient time had been allowed for the deposit in the water to settle in the tank. The effect of this was that lime was carried into the boiler, and this, together with the deposit which would naturally accumulate during working, choked the tubes. (Editorial in *The Power Engineer*, vol. 22, no. 252, March, 1927, p. 82, *p*)

An Oil-Controlled Steam-Pressure Regulator

THE main advantage claimed for this device is its ruggedness and reliability. The control cylinder is mounted on the valve chamber which contains disk or double-beat drop valves. The principle of operation of the device is shown in Fig. 14. The steam pressure is opposed by the action of a spring of adjustable tension. Any variation in pressure causes a motion of the regulator diaphragm which is transmitted by means of a system of levers to the regulating plunger; this allows oil to flow in under the control piston or the other way, causing the valve to be opened or closed. The regulating plunger thereupon immediately returns to its original position.

There are many ways to use these regulators. For instance, the regulator can open the valve when the pressure rises in front of it, but close it when the pressure behind the valve has reached a definite value. The regulator shown in Fig. 14 is a single-impulse regulator. A three-impulse regulator may be used, for instance, to open the valve when the pressure in front of it rises, to close it when the pressure beyond it has reached a definite value, and

to re-open it as soon as the pressure beyond it has gone down to a certain minimum value, independently of the pressure in front of it. The regulators are equipped with a device by means of which the pressure may be adjusted at any time, even during service, within comparatively wide limits, or the regulator may



a = Diaphragm,
b = Levers,
c = Pressure Oil Inlet,
d = Oil Outlet,
e = Control Piston,
f = Regulating Plunger,
g = Steam Pipe,
h = Hand Wheel for Adjusting the Pressure,
i = Pressure Indicator,
k = Disengaging Lever; Valve in Operation,
l = Disengaging Lever; Valve out of Service,
m = Waste Oil Drain Pipe,
n = Diagrammatic Sketch,
o = Steam Inlet,
p = Steam Outlet.

Fig. 14 Single-Impulse Oil-Controlled AEG Steam-Pressure Regulator

be cut out completely. (Dr. of Engrg. E. A. Kraft, Turbine Dept., German General Electric Co., in *AEG Progress*, vol. 2, no. 7, July, 1926, pp. 168–169, 2 figs., *d*)

Electric Boilers

A general discussion of the subject. The most interesting part is that dealing with Penzold electric boilers for high-tension single-phase or three-phase boilers. In this system cylindrical bodies (Fig. 15) are arranged around the high-tension electrodes, with the result that the radial current path has such a section that the energy will not be converted at the anodes. At the electrodes there is a very large cross-section of the liquid, so that there is little heating effect at these especially important points. The high resistance of the circuit is formed by a narrowed zone of liquid between two round porcelain disks. Steam is formed to the greatest extent at the narrowest point, i.e., at the point furthest from both electrodes. The steam bubbles which form there do not affect the passage of the current from the electrode to the water, so that there is no sparking or fluctuation of the current.

The output is regulated only by means of the water level, there being no built-in mechanical regulating drive. The active quantity of water is increased or decreased by raising or lowering the height of the water surface without altering the length of the path of current in any way. The boiler water is thus always subject to the same voltage conditions, and the boiler may be adjusted for different conditions and outputs within certain limits by adjusting on the site during erection the distance between the individual displacement bodies. When doing this it is unnecessary to maintain an exactly centered arrangement as no mechanical regulating drive has to be considered.

For boilers up to 10,000 volts service pressure, all three electrodes are mounted in the same boiler shell. A space of 200 to 300 sq. ft. is sufficient for all parts to be accessible for inspection. For tensions exceeding 10,000 volts, each electrode has its own

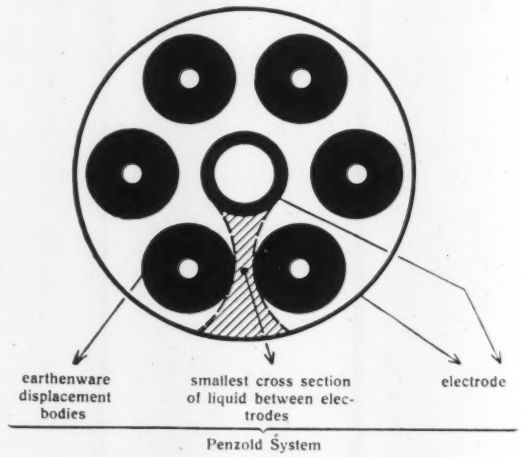


Fig. 15 Penzold Electric Boiler

boiler shell. Proper attention to cleaning of the boiler is important. (*AEG Progress*, vol. 2, nos. 1 and 2, April, 1926, pp. 40–44, 4 figs., *d*)

Explosion of an Autogenously Welded Boiler

In an article which appeared in *Le Génie Civil* in 1910, Ch. Fremont, a well-known French metallurgist, indicated the dangers of acetylene welding as applied to such pressure vessels as boilers. Later he carried out other investigations, among them being one on a Field boiler which exploded in 1925 after a service of only a few months. The explosion took place in the welded part over a length of 1.5 m. (60 in.). An investigation of samples taken from this boiler showed that the welding was decidedly defective and that the jointed parts were only stuck together; furthermore the metal itself was contaminated by segregation and showed brittleness on tests. The conclusion which Fremont arrives at is that the French regulations for welding of pressure vessels are decidedly insufficient to prevent the occurrence of accidents. It would appear that the regulations adopted by the Central Commission of Steam Apparatus make no restriction against the use of steel affected by segregation or brittle steel, and permit the employment of acetylene welding in every way. The Ministerial Commission on Standardization is silent on the subject of acetylene welding, no longer prescribes corrosion tests, and permits carrying out brittleness tests on machines which, according to Fremont, do not indicate with sufficient certainty the presence of brittleness. The article is illustrated by enlarged photographs of sections of the boiler affected by the explosion. (*Le Génie Civil*, vol. 90, no. 10, Mar. 5, 1927, pp. 245–246, 2 figs., *pe*)

Steam Traps

An auxiliary that is the source of much lost heat and is generally neglected as well as being misunderstood, is the steam trap. Even the system of listing traps is illogical. The determining feature of a trap is its capacity, yet it is common practice to list them according to the size of the inlet pipe. About six years ago the author witnessed a test of eighteen competitive 2-in. traps. All were tested under identical conditions, yet one had a capacity of 2000 lb. per hr. and another a capacity of 75,180 lb. Nine had capacities of less than 10,000 lb.; five had capacities between 10,000 lb. and 20,000 lb.; one had a capacity of 30,000 lb., one 40,000 lb., one 64,000 lb., and one 75,180 lb. All of these traps were catalogued as 2-in. traps. They should be rated by capacity at a standard pressure. The capacity depends upon the difference between inlet and discharge pressures and upon the size and shape of the opening. All manufacturers will meet their guaranteed

capacities and all traps will work satisfactorily when new except where the condensate is not clean and small valve openings may become plugged. The determining factor is generally the length of time that the trap will continue to work satisfactorily. The requirements for a serviceable trap are few operating parts, which should be rugged and accessible, a perfect seal to prevent steam escaping with the condensate, a valve of large area and not susceptible to wire drawing, motive power sufficient for quick and positive valve action, a liberal capacity in the water chamber, and sufficient capacity to discharge condensate as fast as it is delivered to the trap. Traps should be bypassed and strainers should be installed in the inlet pipe. It is also advisable to have a pocket in the bottom of the trap for blowing down any sediment that may accumulate. An air vent and gage glass should also be installed. One of the most uneconomical traps is the type that discharges into an open system or at atmospheric pressure. Condensate from a 150-lb. steam system will have a temperature of 366 deg. fahr. and, if discharged into the atmosphere at a temperature of 70 deg. fahr., will release 366–70 = 296 B.t.u. per lb. This excess temperature flashes and creates a small amount of steam which escapes into the atmosphere. If the trap leaks, and a very great number do, there will be more than 1000 B.t.u. in every pound of escaping steam. Where the condensate is discharged into a closed system of lower pressure, the excess heat remains in the system and is not lost. Return or lift traps should be used where possible. (F. M. Gibson (Mem. A.S.M.E.) in *Industrial Management*, vol. 73, no. 3, March, 1927, pp. 177–183, 6 figs., *p*)

The Manufacture of High-Pressure Boiler Drums

HIGH-PRESSURE boiler drums cannot well be made under present methods by riveting. Hence the recent high-pressure drums have been made chiefly by forging, this process being employed in Germany by Krupp, and in America for the 1200-lb. Boston boiler. Thyssen & Co., however, have developed a method under which they claim to be able to make high-pressure vessels by welding. Among other things, they made about 800 hydrogen containers during the war for the German Government. These containers were about 15 m. (49.2 ft.) long with a diameter of 900 mm. (35.4 in.) and had a wall thickness varying from 38 mm. (1.49 in.) to 41 mm. (1.61 in.). They had to withstand a working pressure of 1420 lb. per sq. in. In a certain instance one of these containers was accidentally destroyed, but under conditions which gave a good opportunity to demonstrate the soundness of a welded seam. While it was being filled a drain cock blew off and the hydrogen escaping under a pressure of 750 lb. per sq. in. became ignited at the orifice. There was nothing to be done but disconnect the container from the filling apparatus and leave it to its fate. The burning hydrogen heated the container locally and created an increased internal pressure, with the result that an immense bulge appeared at the heated part, the metal being stretched from its initial thickness of 41 mm. to 5 mm. (1.61 in. to 0.19 in.) before rupture took place. The whole of the surface of the container was found afterward to show evidence of strain, but in spite of this neither the circumferential nor the longitudinal welded seams gave way at any point.

The plant now contains a reversing mill capable of dealing with ingots weighing 30 tons, from which latter plates of a finished weight of 16 to 18 tons can be made. The maximum finished width of plates from this mill is 4220 mm. (165.78 in.) with a length of 16 m. (52.48 ft.). From such plates a boiler drum with an internal diameter of 1250 mm. (49.20 in.) can be constructed with a single longitudinally welded seam.

A proper amount is trimmed off from the plate to insure absolute soundness of the remaining metal, whereupon the sheared plates are thoroughly annealed to remove the strains induced, among other things by the shearing itself. In the welding shop the plates have their edges planed to a bevel edge for making the subsequent lap joint. Next they are bent to shape and thereafter welded. The method of welding is somewhat like that of the hammer weld used in this country, the metal being heated in spots by a water-gas flame and then welded by hammer blows against an anvil carried inside.

The whole process is described in the original article and shows that the material has to be annealed a good many times. Data are given in tests showing the character of the weld. (*The Engineer*, vol. 143, no. 3712, Mar. 4, 1927, pp. 246–248, 11 figs., *d*)

Thermal Methods of Feedwater Preparation

MODERN power-plant engineering has found that with present high boiler pressures and outputs it is not sufficient to purify feedwater by ordinary chemical means, and further that feedwater must be very carefully freed of dissolved gases. Distillation would appear to be the means most effectively combining both of these requirements.

In the past both on land and water a half-hearted effort was made to achieve this and to use only distilled water as make-up, but until the last few years the matter was not taken up in real earnest. On shipboard fresh water was carried between bottoms; an evaporator was provided, however, for emergencies. In this evaporator live steam was used at pressures of from 2 to 8 atmos., i.e., at temperatures at which there was a particularly powerful separation of salts and scaling of the tubes. As a result the efficiency of the evaporator rapidly went down. Furthermore, unless considerable care was exercised the evaporator easily boiled over and salt was carried over into the boiler. Finally, the heat losses were so great that it took 1.2 lb. of live steam to produce 1 lb. of distilled water, and the distillation steam was conducted as a rule into a condenser where its latent heat was lost. Even before the war a suggestion was made to feed the evaporator with exhaust steam from the auxiliary engines instead of with high-pressure live steam; but it was not put into practice until long after the war, and then only under the pressure of competition with the Diesel engine and the like. At this time an exhaust-steam evaporator of a type shown in the original article was introduced and found rapid adoption. This evaporator was supplied with exhaust steam having a pressure of 1.5 atmos. gage. It therefore did not make an additional demand on the boiler, and the heat content in the evaporated steam was regained in the feedwater preheater. Under these conditions, of course, the evaporator ceased to be an emergency device and became a regular element of the ship power plant.

A further result of the new arrangement was that it ceased to be necessary to supply large amounts of make-up water to the boiler, the exhaust-steam evaporator recovering the water. The new arrangement also eliminated the necessity of taking up valuable space by carrying water tanks, and because of the freedom of the water from scale-forming matter, times between boiler cleanings were greatly increased as compared with previous practice.

In commercial shipping the necessity of feeding the boilers with distilled water has been quite widely recognized recently and will be appreciated still more as boiler pressures increase and water-tube boilers are more extensively introduced on shipboard. Naturally, the evaporator has to be correctly designed from the thermodynamic point of view, and the author recommends two-stage preheating where in one stage auxiliary steam is available at high pressure and in the other at low pressure. The exhaust steam from the majority of engines on shipboard is so high that it can be used to supply an evaporator and a surface preheater, while the process steam from the evaporator goes into a mixed preheater where it is usually helped out with exhaust steam from light machinery. In such an installation preheating can be easily carried to from 120 to 130 deg. cent. (248 to 266 deg. fahr.). This arrangement is all the more economical as regards saving space and weight because it permits providing auxiliary machinery with piping which would be too small for low-pressure exhaust steam, which latter requires large, expensive, and heavy piping, increasing both the weight and cost of the installation. The steam from the winches may be used in the evaporator. This practice makes it possible to obtain a small reserve of distilled water to be carried in tanks.

As regards degasification of water, this can be best carried out in mixed preheaters, possibly by a deaerating cap set on the surface preheater. No particular attention is paid today to degasification of feedwater on shipboard as trouble due to corrosion is not very serious, partly because of the comparatively low working pressure now used and partly because of the fact that the condensate from exhaust steam from the auxiliary machinery is always somewhat oily. With the increase of boiler pressure much more

serious attention will have to be paid to this subject, because then the content of gas which is comparatively harmless today will begin to produce material corrosion.

Furthermore, a water-tube boiler evaporates its quota of water much faster than present ship boilers, which means that the air supply will be greater. The assumption that so long as the vacuum

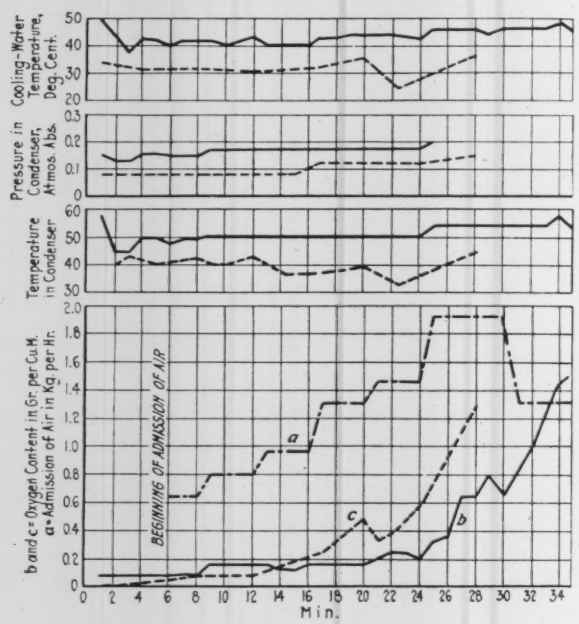

Cooling-Water Temperature, Deg. Cent.
Pressure in Condenser, Atmos. Abs.
Temperature in Condenser
b and c = Oxygen Content in Gr. per Cu. M.
a = Admission of Air in Kg. per Hr.
BEGINNING OF ADMISSION OF AIR
a
b
c
Min.

Fig. 16 Air Content in Water of Condensation When Air Is Deliberately Admitted into the Exhaust-Steam Pipe Leading to Condenser

(Broken line = test with initial vacuum of 91 per cent = 0.09 atmos. abs.; solid line = test with initial vacuum of 84 per cent = 0.16 atmos. abs.)

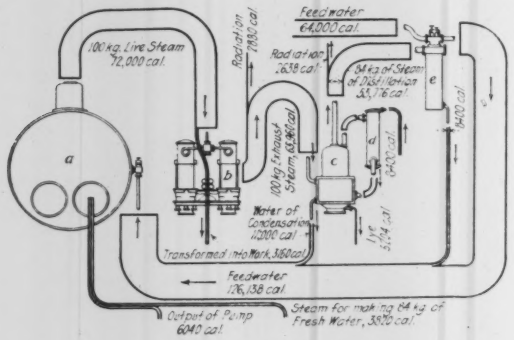


Fig. 17 Heat-Balance Diagram in Large Calories for Marine Steam Power Plant Using Water Preheating and Make-Up Water Evaporation by Exhaust Steam

(*a*, boiler; *b*, feedwater pump and auxiliary machinery; *c*, evaporator; *d*, water preheaters; *e*, preheater with 2-stage evaporation.)

is constant there can be no air in the condensate, is incorrect. Apart from the possibility of leakage through the pumps, the water of condensation in the state in which it leaves the condenser may contain dissolved air, notwithstanding the fact that the vacuum may not seem to be affected.

To prove this the following tests were carried out. First, the oxygen content in the water of condensation back of the condenser was determined, care being taken to see that the exhaust-steam pipe was perfectly air-tight. It was found that the oxygen content was 0.08 gram per cubic meter with an average vacuum of 84 per cent and a temperature of water of condensation of 51 deg. cent. (123.8 deg. fahr.). Then air was admitted through a metering nozzle into the exhaust-steam line. The oxygen content in the water of condensation jumped immediately to 0.16 g. per cu. m. (Fig. 16), while the vacuum went down very gradually to 83 per cent. With further addition of air the vacuum remained stationary at 83 per cent until the oxygen content in the water of condensation increased to 0.22 g. per cu. m., or nearly three times its initial value. When the vacuum dropped to 0.8 the oxygen content in the water rose to as high as 0.8 g. per cu. m. A similar test with a 91 per cent vacuum gave still higher values for the dissolved-air content. These tests show that in the case of exhaust-steam-pipe leaks, a share of the air thus admitted is absorbed by the water. Furthermore, air which enters in this way can produce quite harmful effects, and in high-pressure boiler plants it is absolutely essential to eliminate it by some proper process. The conclusion to which the author comes is that feeding the boilers with distilled water is easily attainable on shipboard and is perfectly justified both from the thermodynamic and economic points of view. The heat exchange in such cases is shown in the diagram of Fig. 17. The question of cleaning the evaporator is one of great importance, particularly on shipboard.

When we come to land installations the most important factor to be considered is the very large scale of operation, entirely different from what takes place on shipboard. On the other hand, the heat loss in central stations can be kept a good deal below that on shipboard. Then again, in order to obtain economical power generation in a central station, it is important to have as many hours of operation as possible with a high base load. The fundamental condition for this is a reliable, uninterrupted running of boilers at high loads, which, in turn, presupposes great care in the preparation of feedwater.

As long as the matter of feedwater preparation was treated exclusively as a chemical process there was no obvious connection between it and the heat balance of the power plant. When it came, however, to making up feedwater by employing a heat process, it became obviously necessary in order to carry it out economically to make it an integral element of the entire system, the problem being to produce the feedwater by distillation of raw water with the minimum consumption of heat, and at the same time to obtain the maximum possible degree of preheating of this water, as well as its perfect freedom from gases.

The thermodynamic and structural solution depends very largely on the amount of make-up water required. In the case of a power plant in which the loss of water amounts to from 3 to at most 7 per cent of the water of condensation in circulation, the latent heat of the evaporate in the distillation plant can be taken up without any trouble by the feedwater, even where the pressure in the evaporator is low. An entirely different situation is encountered, however, in industrial establishments, where the amount of make-up water may run up to 30 per cent or more of the water of condensation, or where exhaust steam is used for process cooking, steam hammers, and the like.

From this the author proceeds to the discussion of central-station practice and shows that it is possible to find a proper solution for the problem of water distillation, whether the boilers are equipped with economizers or with reheaters and air preheaters. He gives certain advice as to how this problem of make-up water should be solved, and describes two-stage and three-stage evaporators. An interesting installation with an output of 16 tons of water per hour forms a part of the Charlottenburg plant of the Berlin Electricity Supply Co. Here the preheating of the condensate in a mixed preheater employs both process steam from the evaporator plant and exhaust steam from the turbine-driven feedwater pump and the cooling-water pump. The temperature attained is of the order of 80 deg. cent. (176 deg. fahr.), and the steam for operating the evaporator is taken from the feedwater pumps and the regenerative cylinder of a turbine and is delivered at a pressure of 3.5 atmos. This installation, diagrammatically shown in Fig. 18, shows how feedwater purification by distillation (which the Germans call "thermal feedwater preparation") can be organized in an existing plant.

Another figure in the original article shows how the same problem is solved in a plant where bled steam for the preheater and a special preheater turbine are available.

In some plants where the belief prevails that chemically purified water will be satisfactory, facilities are installed for degasifying this water, and it is possible to obtain a good deaeration of chemically purified water by thermal means. It is important to remember that water which has been first chemically purified and then deaerated produces at higher pressures separation of soda, which in turn leads to the formation of carbon dioxide and caustic soda, which latter produces corrosion in the boiler. Such a pro-

cedure does not permit complete elimination of combined carbon dioxide.

The original article gives particulars of a German installation made at the Cellina central station in Venice, where bled steam is used for heating and the water is raised to a temperature of 65 deg. cent. (149 deg. fahr.). The advantage of this kind of

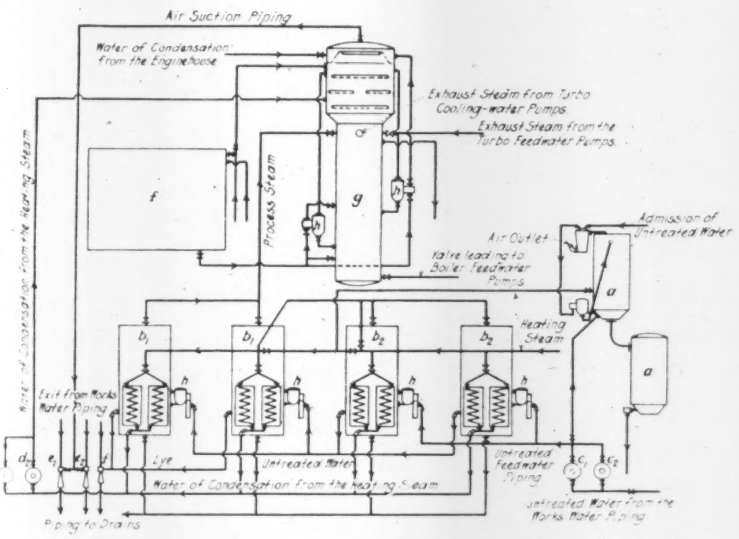

Air Suction Piping
Water of Condensation from the Enginehouse
Exhaust Steam from Turbo Cooling-water Pumps
Exhaust Steam from the Turbo Feedwater Pumps
Process Steam
Admission of Untreated Water
Air Outlet
Valve leading to Boiler Feedwater Pumps
Heating Steam
Exit from Works Water Piping
Lye
Untreated Water
Untreated Feedwater Piping
Water of Condensation from the Heating Steam
Untreated Water from the Works Water Piping
Piping to Drains

FIG. 18 FEEDWATER PREPARATION BY DISTILLATION WITH TWO 2-STAGE EVAPORATORS, A DELIVERY OF DISTILLED WATER OF 16 TONS PER HR., AND DEAERATION OF WATER OF CONDENSATION OF 300 TONS PER HR.

(*a*, mixed preheater and degasifier I; b_1, evaporator I; b_2, evaporator II; c_1 and c_2, untreated-feedwater pumps; d_1 and d_2, pumps handling the water of condensation from heating steam; e_1 and e_2, water-jet air pumps for the mixed preheaters; *f*, lye ejector; *g*, mixed preheater and degasifier II; *h*, governor; *i*, feedwater tank.)

degasification consists in the fact that the degasifying unit may be located ahead of the boiler-feedwater pump and that the degasified water goes directly into the boiler. All devices for protecting the feedwater tanks from gas absorption may be eliminated since all water, even that taken from the tanks, is degasified before being admitted to the feedwater pumps.

Among the various installations described is one provided with a jet compressor. (R. Blaum, Bremen, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 71, no. 9, Feb. 26, 1927, pp. 285–290, 12 figs., *pd*)

RAILROAD ENGINEERING

Canadian Pacific Locomotive with Nickel-Steel Boiler

PACIFIC and Mikado type locomotives of 42,600 lb. and 56,300 lb. tractive force, respectively, have been the standard heavy passenger and general freight-service locomotives on the Canadian Pacific for the past eight years. When the question of additional power was being considered in 1926, it was decided that in general these two classes of locomotives should be perpetuated with the exception that such improvements in capacity and efficiency would be made as were possible without increasing the weight beyond a rather narrow range.

Modifications eventually decided on included an increase in boiler pressure of 25 per cent or up to 250 lb. pressure per sq. in., the use of feedwater heaters, the use of front-end throttles, and the operation of auxiliaries by superheated steam. The application of the Elesco closed type of feedwater heater with a C-F1 class duplex pump, accounted for the increase in weight of 6000 lb. To increase the boiler pressure 25 per cent and at the same time to keep within a total locomotive weight increase of two per cent would, on the face of it, appear an impossibility. But in doing this, the Canadian Pacific put into effect a step in locomotive construction that it has been investigating and considering for a considerable length of time. This was the use of nickel-steel boiler plate of 70,000 lb. per sq. in., minimum tensile strength, which permitted on the two designs of locomotives under discussion an increase in boiler pressure up to 250 lb. per sq. in. without any change in the thickness of the barrel course plates.

The boiler has been changed very little over the base design for 200 lb. pressure. It is of the radial-stay type, and beyond the thickening of the wrapper sheet and firebox side sheets and a careful investigation and checking of all details of construction, there are practically no changes made other than the substitution of nickel-steel boiler plate for carbon steel in the first, second, and third course sheets and welt sheets, and the use of steel for longitudinal braces of the boiler.

The nickel-steel boiler plate is open-hearth basic steel made and rolled by the Lukens Steel Company with the joint inspection and coöperation of the American Locomotive Company, the International Nickel Company, and the Canadian Pacific. It was anticipated that the plates would have a somewhat pitted surface typical of nickel steel, but the surface conditions were quite equal to carbon-steel boiler plate. The use of nickel steel effects a saving of 27 per cent in the weight of the barrel-course sheets, or permits the use of higher pressure without a corresponding weight increase.

This being the first alloy steel produced by the Lukens Steel Company, there was some preliminary work and investigation required before the material was finally produced on a commercial basis, but once started, very uniform material was produced. To illustrate, an analysis was made of the physical properties of 465 determinations of nickel-steel boiler plate and an equal number of carbon-steel boiler plate on a previous order for locomotives. The average results obtained on the nickel steel were: yield point, 46,800 lb.; elongation, 26 per cent, and reduction of area, 53 per cent. The average tensile strength and yield point for carbon-steel boiler plates ran 59,200 lb. and 36,200 lb., respectively, so that the gain in strength based on an average of the results obtained is 29 per cent on both the ultimate-strength and yield-point bases.

The maximum variation in the various physical properties above and below the average were found to be almost identical for the nickel-steel and for an equal number of carbon-steel determinations.

The nickel material is remarkably rough and ductile, and generally speaking, in the transverse bend tests the heaviest plate can be bent flat on itself without fracture. Specification requirements call for bending of the plate around a pin, the diameter of which is equal to a certain percentage of the plate thickness, this being worked on a sliding scale based on the usual practice for carbon steel. As nickel steel stood this readily, the tests were usually carried further until the plate would bend flat on itself and an illustration in the original article shows a typical specimen which illustrates the ductility of the material and its ability to withstand the transverse bend tests. From the shop viewpoint there is little if any difference between nickel and carbon steel as regards punching, drilling, or reaming.

Alloy steels are used quite extensively elsewhere on the locomotive as well. Thus, among other things, the frames are of carbon-vanadium steel.

Several minor improvements have also been introduced: for example, the use of an outside connected throttle, and extension handles for all auxiliary valves to one central point in the cab to permit maximum ease of operation. (*Railway Age*, vol. 82, no. 16, Mar. 19, 1927, pp. 928–930, *d*)

SPECIAL PROCESSES (See Power-Plant Engineering: The Manufacture of High-Pressure Boiler Drums)

WELDING (See Power-Plant Engineering: Explosion of an Autogenously Welded Boiler)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,
Aeronautic Division
H. W. BROOKS,
Fuels Division
R. L. DAUGHERTY,
Hydraulic Division
JAMES A. HALL,
Machine-Shop Practice Division
CHARLES W. BEESE,
Management Division
G. E. HAGEMANN,
Materials Handling Division
J. L. WALSH,
National Defense Division
L. H. MORRISON,
Oil and Gas Power Division
W. R. ECKART,
Petroleum Division
F. M. GIBSON and W. M. KEENAN,
Power Division
WINFIELD S. HUSON,
Printing Machinery Division
MARION B. RICHARDSON,
Railroad Division
JAMES W. COX, JR.,
Textile Division
WM. BRAID WHITE,
Wood Industries Division

Aeronautics

Airplanes for Commuter Service[1]

A-15 What are the prospects of the employment in the near future of very large airplanes for the transportation of passengers in commuter service in the United States?

(*a*) Large passenger airplanes of the three-passenger type have been very successfully employed by the Philadelphia Rapid Transit Co. in its Washington–Philadelphia route. There are indications of a revival in passenger carrying, and large multi-engine ships are sure to be employed in such service. The Colonial Air Lines are purchasing such ships. (Alexander Klemin, Professor of Aeronautical Engineering, New York University.)

(*b*) Regarding this subject, as discussed in the March, 1927, issue of MECHANICAL ENGINEERING, city-planning experts have found that the mass of the population will not live at a distance greater than one hour's travel from their place of business, and that as soon as faster methods of communication at a reasonable cost become available a vigorous movement begins which shifts the external city fringe of population to the new limit of one hour. We are rapidly approaching a state of development where airplanes carrying one hundred passengers will become a possibility, and where under these conditions the cost of transportation for one hour's flying will not be in excess of ten cents on a regular schedule. As soon as this happens communities within, say, seventy-five miles from Grand Central Station will come within commuting distance of New York City, and this traffic would then create a demand, which obviously can be satisfied, for still bigger machines. As only one or two landing fields in the city will be required, this problem is not a formidable one. It is therefore entirely possible that commuter traffic may become the first really important application of commercial aviation in the United States. (L. C., New York, N. Y.)

Landing-Speed Reduction[1]

A-16 What efforts are being made to reduce the landing speeds of airplanes?

Many constructors are making earnest efforts to decrease the landing speeds of airplanes through the use of wing flaps, wing slots, etc., either singly or in combination. It is not solely a problem of reducing the landing speed, but is a problem of how to reduce the landing speed and still keep the same high speed. In other words, an increase in the speed range of the machine. As in many other instances in aviation, this question is a compromise between slow landing speed and heavy pay loads. (Richard H. Depew, Jr., Vice-President, Fairchild Flying Corporation, New York, N. Y.)

[1] This subject has been discussed in a previous issue.

Fuels

Properties of Steam and Gas Coals

F-13 What are the properties of a good steam coal and a good gas coal, respectively?

(*a*) Steam coal should be clean, properly prepared lump bituminous or semi-bituminous, without visible slate or other dirt. The grade should be $\frac{3}{4}$ in. to $1\frac{1}{4}$ in.; ash, five to ten per cent and not over twenty per cent; B.t.u., average 13,000, not less than 10,000. Dust in small pieces should constitute a very small proportion of the total coal. The writer is unable to furnish sufficiently valuable information on the properties of gas coal to justify an attempt to answer that portion of the question. (J. G. Worker, Asst. to the President, American Engineering Company, Philadelphia, Pa.)

(*b*) Good steam coal: Moisture not over three per cent; volatile matter, fourteen to twenty per cent; ash, not over eight per cent; heat value per lb. of combustible (based on ash and moisture-free coal) not less than 15,600 B.t.u.; coke should swell and cohere during combustion and retain strength after formation; fusion temperature of ash, 2500 deg. fahr. or above; freshly mined coal preferable. Good gas coal: Volatile matter, thirty to thirty-eight per cent; ash, not over eight per cent; coke should have properties as described above; freshly mined coal preferable. (W. E. Caldwell, Asst. to Genl. Supt. of Power Plants, United Electric Light & Power Co., New York, N. Y.)

Hydraulic

H-1 To what extent have companies attempted to operate hydraulic turbines without governors?

The subject of installation and operation of hydroelectric units without governors has aroused considerable interest and discussion within the past two or three years. It is the understanding of the writer that several small plants have been so installed, both in the East and the Far West, and have given satisfaction so far as possible to ascertain from a questionnaire sent out. Such plants must necessarily form only a small portion of the capacity of the system into which they are feeding, for the reason that they are likely to disconnect themselves from the system practically, if not entirely, without warning, and furthermore are likely to cause disturbances to voltage and frequency when connected to the system. It is customary to bring them up to about 95 per cent of full speed before throwing in the circuit breaker, with the expectation that the time lag of the circuit-breaker operation will be such that the frequency of the unit will be almost exactly synchronous with that of the system when the breaker closes. Should this not prove to be exactly the case, disturbances will take place, the extent of which will be proportionate to the ratio of the plant capacity to the connected system capacity. (Byron E. White, General Engineer, Utica Gas and Electric Company, Utica, N. Y.)

H-2 Has anything been done to provide a guide-bearing for large high-head, vertical-shaft turbines which will enable the turbine runner to have a smaller clearance than has heretofore been necessary?

The company with which the writer is connected has a type of design of bearing having spherical or conical bearing surfaces, which eliminates practically all lateral motion of the shaft except what may be due to elasticity of the shaft and bearing supports.

The company has not heretofore applied this on vertical hydroelectric units, but at the present time is proposing it for an important hydroelectric development. (Albert Kingsbury, President, Kingsbury Machine Works, New York, N. Y.)

Railroad

DESIGN OF RAILWAY ELLIPTICAL SPRINGS

R-9 In checking over the designs of railway elliptical springs it is found that there is disagreement as to the effect of the bands, some considering that it restrains the action of the leaves, and others ignoring it entirely. There is likewise a difference in the modulus of elasticity used, which affects the deflection value of the spring. Another variation is in the length used in determining the characteristics, some using total length and others the net length. Exchange of information with members through this department should prove helpful.

In applying the beam formula to the problem of springs the initial step is to consider one end only of a half-elliptic spring, assuming that portion to be a cantilever beam fixed at one end and loaded at the other. The length of the cantilever would be the distance from the point of load application to the edge of the mechanism forming the fixed end (see l of Fig. 1-A). A half-elliptic spring being two such cantilevers extending in opposite directions from a common support, the effective length is $2l$, or the span less the width of the band.

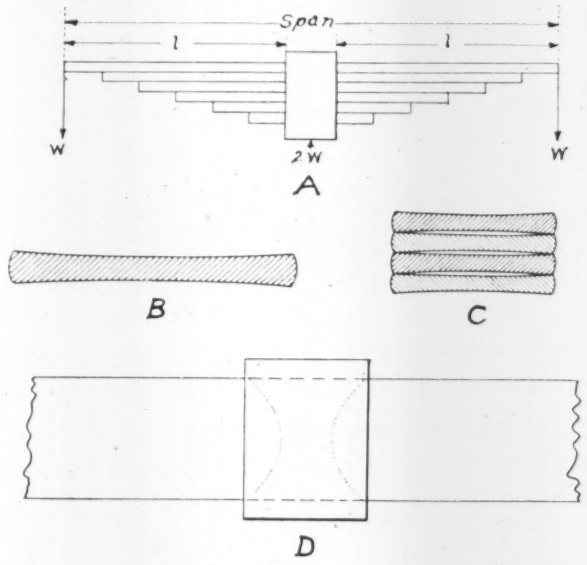


FIG. 1

It must be very clearly noted and understood that the above is based on the assumption that one end of the cantilever is *rigidly fixed*, and therefore no stress will be developed in the material confined by the fixing device. However, springs broken in service often have one or more leaves broken at a point within the band, and sometimes leaves are found broken at the exact center, indicating that stress *is* generated within the band.

Spring-steel bars are usually rolled with rounded edges and concave surfaces (see Fig. 1-B in which the concavity is exaggerated). The actual width of the bar varies within a small tolerance up to about $^1/_{32}$ in. for wide sizes. The total concavity of the two surfaces together being about three- or fourth-tenths of one per cent of the width. The band is a plain forging of wrought iron made with an opening a little larger than the bundle of spring leaves. The heated band is applied over the leaves and the excess size reduced by squeezing the hot metal to the leaves.

On subjecting the spring to its first compression, the pressure of the leaves against the inner faces of the band dislodges bits of scale, which together with a little rounding of the edges of the band permits the leaves to move a little at the immediate edge of the band, the movement extending to a depth sufficient to be quite appreciable. Furthermore, the concave leaves have actual contact with each other only along their edges, with a minute opening or gap at the center between each pair of leaves (See Fig. 1-C). This opening will permit a slight movement of the leaves at the center, producing a complicated network of stresses with a line of maximum stress somewhat as shown by the dotted-line curves at D of Fig. 1.

As neither the extent of loosening of the leaves within the band nor the effect of the concavity is regular and uniform, the only practical way to make allowance for these factors is by the use of a close average based on observation of a great many cases.

The writer has made many tests and has examined a large number and variety of broken springs, from which the conclusion has been drawn that a fully practical and sufficiently accurate allowance may be secured by assuming two-thirds of the band to be inactive. Therefore, in the use of the beam formulas the length to be taken is the distance center to center of the end bearings minus two-thirds the width of the band; the figure to be taken being the length of the arc of the main leaf, rather than the span.

The condition covered by this question has an important bearing on the life and service of plate springs and would seem to be a very pertinent subject for thorough investigation by the Society's Committee on Mechanical Springs. (Alexander S. Henry, President, Railway Steel-Spring Co., New York, N. Y.)

VALVE MOTION FOR THREE-CYLINDER LOCOMOTIVES

R-10 What type of valve motion is used on three-cylinder locomotives?

(*a*) The outside valves of three-cylinder locomotives are fitted with either Walschaerts or Baker gears. The middle valve is actuated by the Gresley gear, which takes its motion from the valve stems of the two outside gears. (James Partington, Manager, Engineering Department, American Locomotive Co., New York, N. Y.)

(*b*) On three-cylinder locomotives, the valves of the outside cylinders can be moved by any of the outside valve gears, such as Walschaerts, Baker, or Southern. The valve for the inside cylinder can be operated by a combination of levers connected to the outside valves or valve gear, such as that patented by Gresley, or the valve can be operated by a Joy valve gear connected to the inside main rod or by an independent Walschaerts valve gear with the reverse link located outside the frame. (Robert S. McConnell, Chief Consulting Engineer, Baldwin Locomotive Works, Philadelphia, Pa.)

Wood Industries

MAHOGANY FINISH FOR OAK[2]

WI-2 What types of stains, varnishes, etc., are recommended to produce a reasonably lasting mahogany finish for an oak stair tread?

A spirit penetrating stain or an acid stain should be used to produce the dark effects—mahogany, walnut, etc.—but in no case should the varnish be applied directly over the stain, as the result will be very unsatisfactory, due to poor drying and to the resulting tacky or sticky effect. In cases of this kind there is no choice but to use a coat of thin, pure white shellac to seal the stain in the wood before applying the varnish. Only just enough shellac should be used to seal the stain effectively. After the shellac is dry, apply three coats of good floor varnish, sanding lightly between coats when dry. (J. A. Bowman, Sales Manager, The Sherwin-Williams Co., New York, N. Y.)

Miscellaneous

GAS INLETS TO SHELL-AND-TUBE-TYPE AMMONIA CONDENSERS[1]

M-3 In vertical shell-and-tube-type ammonia condensers, what have operation results indicated to be the most desirable point of admission of the gas into the shell?

The writer has made tests with gas entering at the top, and also at the bottom, with but slight difference in results. However, this difference was in favor of the top entrance, which gave a slightly lower condenser pressure under the same conditions. The differ-

[2] This subject has been discussed in a previous issue.

ence was so slight that it is probable that admission at the center would show practically no gain or loss. (George A. Horne, Manager, Technical Department, Merchants Refrigerating Co., New York, N. Y.)

Liquid-Ammonia Pump for Cold-Storage Plant

M-4 In a certain electrically driven cold-storage plant having the ammonia condensers located near the ground floor it is necessary in the winter to reduce the condenser surface to create sufficient pressure to deliver the liquid ammonia to the evaporating coils in the upper-floor rooms. The difference in head pressure between summer and winter operation is about 50 lb. per sq. in., corresponding to a head pressure of approximately 200 ft. of liquid ammonia. Would it be practicable from the standpoint of maintenance to install a liquid-ammonia pump to supply the coils and allow the compressors to operate on a lower head pressure with full condenser cooling surface? The pump would be required to handle a maximum of 50 gal. per min. against a head of 125 to 150 lb. per sq. in., including friction, with a suction head of about 75 lb. Could such a pump be made automatic, or pressure-controlled, so that it would need to run only when the pressure conditions were such that insufficient refrigeration was being obtained on the upper floors?

Unfortunately, insufficient information is given to permit an entirely satisfactory answer to this question. No mention is made of the ammonia suction pressure under winter operating conditions when the condenser pressure seems to be at the lowest point of 75 lb. per sq. in. Furthermore, the height of the topmost cooling coils above the ammonia receiver is not given. To illustrate the importance of this information the writer feels quite positive that the problem can be solved without the use of a liquid-ammonia pump. For instance, if the suction pressure is not over 20 lb., there will be a difference of 55 lb. between the discharge pressure and the suction pressure. This for liquid ammonia at 40 lb. per cu. ft. represents a static head of 198 ft. The writer seriously doubts that the highest coil to be fed with ammonia is 198 ft. above the liquid receiver. If, therefore, the liquid mains are of the proper size, properly insulated, if the expansion valves are large enough and the liquid ammonia is first cooled to its boiling point at 20 lb. gage, it will go to the point where it is needed. If the liquid is not cooled and there should be a pressure drop due to a height of the top coil sufficient to cause it to evaporate partly or entirely on the way up, of course no liquid will pass through the expansion valves.

To answer the question direct, the writer would say that a liquid pump can be used and should be used in preference to raising the condenser pressure. It would not be difficult to have such a pump control the pressure automatically. However, as before stated, the chances are 99 to 1 that the liquid pump is not necessary, nor does the condenser pressure have to be raised. (Fred Ophuls, President, Ophuls & Hill, Inc., New York, N. Y.)

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

The Design of Dished Heads of Pressure Vessels[1]

To the Editor:

The design and construction of pressure vessels which will be safe at high pressures is a problem of great engineering importance. These vessels are a necessity in many industrial processes, for example, for "cracking" petroleum. The fact that the vessel described in Mr. S. W. Miller's paper of the above title, designed in accordance with the Pressure Vessel Code of the A.S.M.E. and welded throughout, did not show any distress at the weld when failure occurred by rupturing the head through the manhole, shows in a striking way that pressure vessels can be successfully welded.

In his paper, which appeared in the August, 1926, issue of Mechanical Engineering (p. 845), Mr. Miller calls attention to the fact that these vessels "showed heavy stress at the knuckle" of the dished head. This is a common experience.

The results of strain-gage measurements on tanks are given in Technologic Paper of the Bureau of Standards No. 243, Stresses in a Few Welded and Riveted Tanks, Tested Under Hydrostatic Pressure, by Stang and Greene.[2]

The subject is of sufficient importance to warrant a much more extensive investigation.

There is evidence that the pressure vessel which Mr. Miller describes failed at the manhole in the dished head. Theoretical analyses of the stresses at the knuckle of a dished head and in the flange of a manhole throw some light on the subject, but the designs which it is intended to standardize should be tested under hydrostatic pressure and many strain-gage measurements taken to give reliable design data.

Because of the rapid change in the stress around openings, places where the radius of curvature changes rapidly and where there is a change in the thickness of the plate, a short gage length is very important. If the gage length is eight or ten inches the computed stresses may be almost valueless. If the gage length is two inches there are appreciable errors in the readings. A strain gage of greater accuracy than the Berry (which is in general use) is highly desirable, particularly for two-inch gage lengths. Here at the Bureau of Standards we have tried a new frame which has several advantages over the Berry frame, but a dial micrometer having a greater accuracy than the rack-and-pinion dials (such as the Ames) and with a longer range than the "Last Word" dial is necessary if the errors in the present instruments are to be materially decreased.

There are one or two designs for a dial which if made with workmanship comparable with that required for high-grade watches would undoubtedly give excellent results, but as in all probability few of them would be required, no manufacturer is willing to make them. This is an illustration of the disadvantages of attempting to carry on investigational work in this country. Either special precision apparatus cannot be obtained at all or the price is excessive.

To be satisfactory for these strain gages a dial micrometer should have a range of about one-tenth of an inch, be graduated to ten-thousandths of an inch, and have no error exceeding one ten-thousandth inch.

Gage lengths of one inch—and for some gage lines of one-half inch—are very desirable.

If the strain gage is attached on the gage line and readings taken through a loading cycle *which does not stress the material at any point beyond the elastic limit*, then the strain gage can be shifted to another gage line and the test repeated. Unfortunately, permanent deformations are likely to occur in these pressure vessels at unexpectedly low loads.

Applying a coating of white portland cement[3] to the surface of the vessel will make the strain lines in the material visible, but does not assist in determining their magnitude.

So far as we can see, very careful consideration must be given to the apparatus used in investigating structures, such as these pressure vessels, and to planning the test program to secure the information which is required.

It is evident from Mr. Miller's discussion that the rules formulated by the Boiler Code Committee should be carefully revised. Permanent deformation at the knuckles of dished heads may not make the vessel unsafe, but apparently there is no reason why the knuckle radius should not be greatly increased, if under test pressure this radius increases greatly. A vessel which is designed to have about the form which it assumes after the proof test would make it unnecessary to use a strain gage whenever the vessel was inspected, and would eliminate the question of whether the deformation was

[1] Published by permission of the Director of the U. S. Bureau of Standards, Washington, D. C.

[2] Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 10 cents.

[3] Miscellaneous Publication of the Bureau of Standards No. 72—Strain Lines. Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

increasing with continued use of the structure. The same reasoning applied to the reinforcing around the manhole.

It is reasonable to assume that more or less empirical formulas could be derived which would give satisfactory results and which would not involve elaborate computations on the part of the designer.

It is fortunate that Mr. Miller has described the experience of his company with these pressure vessels so fully that no one can claim that the failure was due to the welding.

The method of fabrication (oxyacetylene welding) was entirely satisfactory. If, instead of welding this tank it had been single-lap-riveted it is probable that the trouble at the manhole would never have developed, because at the highest test pressure the stress in the shell was 27,000 lb. per sq. in. This was 47 per cent of the ultimate strength of the steel. The efficiency of a single-riveted joint is about 50 per cent;[4] but a riveted joint will leak, so that it is impracticable to maintain the test pressure in the vessel long before the ultimate strength of the riveted joint is reached.

Looking at the matter in this way one realizes the advantages of welds, when properly made, over rivets.

H. L. WHITTEMORE.[5]

Washington, D. C.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquires must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given interpretations of the Committee in Cases Nos. 538 544 inclusive, as formulated at the meeting of February 18, 1927, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 538

Inquiry: An interpretation is requested of the term "brass" in Par. P-321 of the Code. Does not this requirement for brass pipe for the water connections to water columns contemplate the use of monel metal or a bronze not containing zinc, the solubility of which in a hydroxide water is much less than that of brass pipe? Furthermore, with alkaline boiler waters that inhibit corrosion, why should not steel pipe or tubing, wrought-iron pipe, or the equivalent be permitted with steam pressures of 200 lb. or less, the same as is specified for pressures over 200 lb.?

Reply: The purpose of the requirement in Par. P-321 for brass, if pipe is used, for the water connections to water columns, is that it was believed that brass would be less susceptible to corrosion, than iron or steel pipe. With hydroxide waters, it is the opinion of the Committee that pipe of monel metal or a bronze not containing zinc will be acceptable as the equivalent of brass. Attention is called in this connection to the fact that the requirement for the water connection applies only if pipe is used for the connection. The preference for the use of brass, if pipe is used for such water connections, is that due to the ordinary lower tendency toward corrosion, there is with most boiler waters a less rapid deposit of scale and impurities from the water than with steel or iron pipe.

[4] Unwin's values, see p. 376, Machinery Handbook, 1st Edition, Tenth Thousand, 1914.

[5] Chief, Engineering Mechanics Section, U. S. Bureau of Standards. Mem. A.S.M.E.

CASE NO. 539

Inquiry: Is it necessary in the construction of double-drum horizontal-tubular boilers, comprising upper and lower drums, the lower of which is a short drum at the rear containing tubes for the first pass of the gases, to follow the requirement of Par. P-314 of the Code for introducing the feedwater above the central rows of tubes, when the lower drum of the pair is so arranged in the setting as to be below the fire line and the blow-off outlet is in so cool a portion of the boiler as to be a desirable point of feeding?

Reply: The boiler described is not of the horizontal-return tubular type contemplated in the second section of Par. P-314 and it is therefore not necessary to introduce the feedwater as therein specified. It is the opinion of the Committee that if the feedwater is introduced into any part of the boiler so that the water will not be discharged directly against surfaces exposed to gases of high temperature or to direct radiation from the fire, the requirements of this paragraph may be considered as met. While the Code does not specifically so state, it is the opinion of the Committee that the boiler should not be fed through the blow-off connection. Attention is called to the fact that this practice is prohibited by the laws of several of the states.

CASE NO. 540

Inquiry: Is it permissible under the requirement in Par. P-301 of the Code for stop valves of the outside-screw-and-yoke type, to use valves of the globe type where the wheel is permanently attached to the spindle and there is no outside yoke?

Reply: It is the opinion of the Committee that if the valve is of such a type of outside-yoke construction that the spindle to which the wheel is permanently attached, rises and falls in such a manner as to give visual indication as to whether the valve is open or closed, it may be considered as the equivalent of the outside-screw-and-yoke type in which the spindle projects through the hand wheel when the valve is open.

CASE NO. 541

(In the hands of the Committee.)

CASE NO. 542

Inquiry: In the application of crown bars for the support of the tops of combustion chambers of wet-back Scotch marine boilers, is it permissible to use crown bars formed of two parallel steel bars or plates with cast-iron legs fitted between them at the ends for legs or rests?

Reply: It is the opinion of the Committee that the rules in Par. P-230 of the Code contemplated the use of wrought steel throughout for crown-bar construction and that cast-iron supporting legs or ends should not be used.

CASE NO. 543

Inquiry: Is it not permissible to attach the markings on steel-plate low-pressure heating boilers by means of a cast plate bearing the information called for in Par. H-68? The second sentence of this paragraph stipulates that the markings shall be "stamped."

Reply: The reference in Par. H-68 to the stamping of the markings on steel-plate low-pressure heating boilers was incorporated therein with the understanding that stamping would be a convenient method of applying such markings on steel boilers, and it is the opinion of the Committee that such stamping directly on the boiler is essential for permanency.

CASE NO. 544

Inquiry: Is it permissible, under the requirement in the last sentence of Par. P-266 to fit boilers less than 24 in. in diameter with a $2^1/_2 \times 3^1/_2$-in. handhole opening and two $^3/_4$-in. washout openings, the latter in order to avoid the necessity of applying pads to the shell to afford the number of threads required by Table P-10 for a 1-in. washout?

Reply: The last sentence of Par. P-266 permits of a handhole opening and two washout openings in addition to the blow-off, for the purpose of washing out the boiler, but it is the opinion of the Committee that this paragraph intended that the washout openings should be at least 1-in. pipe size.

Engineering and Industrial Standardization

Recent Approvals by A.E.S.C.

Safety Code for Building Exits sponsored by the National Fire Protection Association. Approved as a Tentative American Standard.

Gas Safety Code sponsored by the American Gas Association and the Bureau of Standards. Approved as an American Standard.

Safety Code for Forging and Hot Metal Stamping sponsored by the National Safety Council and the American Drop Forging Institute. Approved as a Tentative American Standard.

Standard for Gib-Head Stock Keys sponsored by The American Society of Mechanical Engineers. Approved as a Tentative American Standard.

Standard for Hard-Drawn Aluminum Conductors sponsored by the American Institute of Electrical Engineers. Approved as an American Standard.

Standard for Plain Taper Stock Keys sponsored by the American Society of Mechanical Engineers. Approved as a Tentative American Standard.

Standard for Spiral Steel Rods for Concrete Reinforcement sponsored by the National Committee on Metals Utilization. Approved as an American Standard.

Safety Code for Rubber Machinery—"Point-of-Operation Hazards of Rubber Mills and Calenders," sponsored by the International Association of Industrial Accident Boards and Commissions and the National Safety Council. Approved as Recommended American Practice.

Standard for T-Slots, their Bolts, Nuts, Tongues, and Cutters, sponsored by the National Machine Tool Builders Association, the Society of Automotive Engineers, and The American Society of Mechanical Engineers. Approved as a Tentative American Standard.

Standard for Wire Rope for Mines sponsored by the American Mining Congress. Approved as a Tentative American Standard.

Standard for Wrench-Head Bolts and Nuts sponsored by the Society of Automotive Engineers and The American Society of Mechanical Engineers. Approved as a Tentative American Standard.

Standardization of Wrought-Iron and Wrought-Steel Pipe and Tubing

ON MARCH 10, 1927, the American Engineering Standards Committee accepted and approved the report of its Special Committee which was appointed to prepare recommendations on (*a*) advisability of undertaking the project, (*b*) its scope, and (*c*) the sponsorship. This report contains, we believe, much of interest to our readers, so it is reproduced below in full.

GENTLEMEN:

Your Special Committee to consider the request of The American Society of Mechanical Engineers to authorize the organization of a Sectional Committee to undertake the standardization of wrought-iron and wrought-steel pipe and tubing, begs to submit its report.

It may be explained that this request of the A.S.M.E. grew out of a recommendation (Minute 1701) of the Sectional Committee on the Standardization of Pipe Flanges and Fittings which had been appointed (Minutes 1641 and 1660) to act as a Special Committee on Approval of a Simplified Practice Recommendation on Wrought-Iron and Wrought-Steel Pipe, which was submitted by the National Committee on Metals Utilization (M. C. 508).

We recommend that this work be undertaken by the American Engineering Standards Committee, the scope of the work to be as follows:

Standardization of the design, dimensions and material of welded wrought-iron pipe, of welded and seamless steel pipe, and of boiler tubing, including pipe and tubing for high temperatures and pressures.

We recommend joint sponsorship by the American Society for Testing Materials and The American Society of Mechanical Engineers.

We recommend that the Sectional Committee be given full scope in every phase of the subject, all existing standards and specifications being thrown into a common pool, out of which the Sectional Committee may develop real standard specifications.

In view of the facts that this subject is one on which a large amount of work has already been done, and that the personnel of the Sectional Committee will naturally contain many individuals who have previously been engaged in this work, we recommend that each member of the Sectional Committee be urged to submit, from time to time, to the membership of the organization which he represents, the various drafts of specifications as they may be developed during the progress of the work, so that his individual judgment may be fortified by those of his confreres; or, if a circularization of the entire membership is impracticable or inadvisable, that he submit said drafts to a carefully selected list of members of his home organization. This subject is one of fundamental importance in the engineering field, and the technical findings of the Sectional Committee should be supported on a broad base of experience and engineering judgment.

All existing specifications will come under the Scope of the Sectional Committee's work. The following are listed as those which have been brought most prominently to the attention of the Special Committee:

1 Specifications for Welded and Seamless Steel Pipe, approved by the A.E.S.C. under sponsorship of the A.S.T.M. (A.E.S.C. Project B 21—1924).

2 Specifications for Welded Wrought-Iron Pipe, approved by the A.E.S.C. under sponsorship of the A.S.T.M. (A.E.S.C. Project B 22—1924).

These two specifications have been since revised by the A.S.T.M., but these revisions have not been through Sectional Committee procedure.

3 Standard Specifications of the A.S.T.M. (Designation A 83—24) for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes. This specification has not been submitted to the A.E.S.C.

4 Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (Designation A 106—26 T).

This specification was prepared by the A.S.T.M. in response to a demand for this class of piping, and in conjunction with the preparation of other materials for high-temperature service suggested by the Sectional Committee on Pipe Flanges and Fittings.

5 Specifications of Wrought-Iron Pipe, welded, black and galvanized, of the Federal Specifications Board No. 242—1924.

6 Specifications of Welded Steel Pipe, black and galvanized, of the Federal Specifications Board No. 162 A.

7 Recommendation of the Division of Simplified Practice of the Department of Commerce, containing tables to limit the number of sizes of standard pipe. This recommendation (M. C. 508) was submitted to the A.E.S.C. for approval, but as above, the Special Committee to whom it was referred recommended withholding approval until further study by the parties interested.

Your Committee believes that this work of standardizing piping may effect the work of the Sectional Committee on the Standardization of Pipe Flanges and Fittings (B 16), but it is probable that such effect, if any, will be slight, and therefore no delay in adopting said standard is advisable; also that the American Standard of Pipe Thread (B 2—1919) may be affected by the findings of this new Sectional Committee.

Respectfully submitted,

WILLIAM J. SERRILL, *Chairman*

W. C. CUSHING	C. B. LEPAGE
I. J. FAIRCHILD	F. N. SPELLER
H. B. GOMBERS	H. N. WALLIN
C. F. HIRSHFELD	C. L. WARWICK

W. C. WETHERILL.

Standard Speeds for Machinery

STANDARDIZATION on a national scale of the speeds of machinery is proposed by the National Electrical Manufacturers Association in a request to the American Engineering Standards Committee to take the matter up with the purpose of simplifying and clarifying the existing situation which is stated to constitute a serious burden on industry through the resulting waste and confusion.

In making the request the Association states:

Under present conditions the curve of the speeds of driven machinery is practically a random distribution without any logical ordering of the values used. As a result of this, the sizes of pulleys, gears, sprockets, etc., which manufacturers have to produce, and which manufacturers, jobbers, dealers, and users must keep in stock, have been multiplied almost endlessly.

While the need for simplification of driving and driven connections has been apparent for years, particularly to producers of electric motors, steam engines, etc., nothing has been accomplished, because without coördination and standardization of the speeds of driven and driving machinery considered together, no satisfactory solution can be obtained.

It is the view of the electrical manufacturers that the proposed standardization which should result in a relatively small number of coördinated speeds for the almost innumerable kinds of machinery,

would afford an easy approach to the problem of simplification and standardization of pulleys, gears, sprockets, etc., and would permit much greater flexibility in the selection and use of both power units and driven machinery, greatly promoting interchangeability of such units, and providing economies for innumerable industries dependent upon such equipment.

As the first step, the American Engineering Standards Committee will convene a general conference of the principal trade associations, technical societies, and other groups interested in this subject.

How Should Capacities of Water-Power Sites Be Stated?

A NATIONAL agreement on the methods of rating the water power of rivers has been tentatively reached according to an announcement by the American Engineering Standards Committee. As the question is one of international importance, the coöperation of other countries is being sought before any final decision is made.

There is probably more confusion with respect to proper units and bases for expressing the capacity of water-power sites than with respect to any other resource which vitally affects the prosperity of peoples and nations. A decade ago when water power was used primarily in connection with local industries, the widespread necessity for uniformity in describing it did not exist. As a result, however, of the great increase in the development of waterpower, resulting largely from improvements in the art of transmitting electric energy, there are now relatively few homes that do not use electric energy that has been generated in part by falling water. Moreover, questions regarding waterpower are rapidly becoming of paramount political importance, as illustrated by activities in cities of the West Coast and elsewhere in connection with municipal ownership; in New York in connection with the utilization of St. Lawrence River; and throughout the nation in connection with the power plant already constructed at Muscle Shoals on Tennessee River and with the proposed development in Boulder Canyon of Colorado River.

In order that these various questions may be clearly understood, it is extremely desirable that there be some uniformity in the terms used so that politicians, laymen, and engineers can state their views in terms which have a definite meaning that is understood by all. Much has happened since Watt, observing horses at work in a British brewery, determined a relation between animal and mechanical power, which he used for expressing the capacity of his small steam engine for performing work; but Watt's horsepower is still in common use for expressing the capacity of the modern hydraulic turbine. Indeed, the term "horsepower" is still almost universally used in this country in expressing the energy of falling water, although the energy when generated is measured and sold on the basis of an entirely different unit—the kilowatt.

This example illustrates one of the problems that is now being considered by the Sectional Committee on the Rating of Rivers organized under the procedure of the American Engineering Standards Committee. The Committee is composed of about forty engineers who are prominent in the hydroelectric industry, representing 28 organizations. The work is being carried out under the official leadership of the U. S. Geological Survey, and Nathan C. Grover, the Chief Hydraulic Engineer of the Survey, is serving as the Chairman of the Committee.

Another question that has been given much consideration by that committee relates to the best way of expressing the fluctuations in capacity of a water-power site caused by variations in stream flow. A 100,000-kilowatt steam plant may be operated at full capacity as long as coal or oil is fed under the boilers; but a 100,000-kilowatt generator in a hydroelectric plant will operate at full capacity only as long as there is sufficient water to run the wheels. In some of the most modern plants the water supply is sufficient to operate the whole plant only during two months in the year. The committee has had to consider how best to present a picture of the effect of the variable quantity of stream flow on the capacity of the site.

After giving these and many other questions consideration for over a year the Committee has tentatively decided that the kilowatt should be used instead of the horsepower as the unit for expressing the capacity of water-power sites; that the capacity shown should express the theoretical potential power without deductions for the losses, which are sure to occur in water wheels, generators, transformers, etc.; and that the capacity should be stated for two rates of flow—one called the 90-per-cent-of-time flow, corresponding to a flow available 90 per cent of the time, and the other called the 50-per-cent-of-time flow, corresponding to the flow available one-half of the time.

It is the desire of the Committee to have these tentative rules discussed fully and frankly by every one interested in hydraulic development in this country, to the end that they may be so modified that as finally adopted they will represent the best American opinion. This problem is also being taken up internationally through the International Electrotechnical Commission with a view to the adoption of Standards, internationally, if possible.

Timely Topics

Design of Transmission Shafting. The proposed American Standard Code for Design of Transmission Shafting in final form is now being voted on by the members of the Sectional Committee on the Standardization of Shafting.

Taper Keys. Two additional standards prepared by this Sectional Committee were recently approved by the American Engineering Standards Committee. They are known as the Tentative American Standard for Gib-Head Taper Stock Keys and the Tentative American Standard for Plain Taper Stock Keys, and may be secured upon application to the Publication Sales Department of The American Society of Mechanical Engineers. Price 20 cents each.

Identification of Piping Systems. The proposed Code for the Identification of Piping Systems is now in printer's-proof form and is being distributed for criticism and comment prior to a letter ballot of the Sectional Committee. The National Safety Council and The American Society of Mechanical Engineers are joint sponsors for this project. Copies of the Code may be obtained from the headquarters of either organization.

T-Slots and T-Bolts. On March 29, 1927, the A.E.S.C. completed its letter-ballot creating the Tentative American Standard for T-Slots, Their Bolts, Nuts, Tongues, and Cutters. This is the first in the group of Small Tools and Machine-Tool Elements to be completed. The standard is now in pamphlet form and may be obtained by addressing either the National Machine Tool Builders Association, the Society of Automotive Engineers, or the A.S.M.E., who are joint sponsors for it. Price 35 cents.

Shell End Mills. The second standard of the group of Small Tools and Machine-Tool Elements to reach the printer's-proof stage in development is that on Shell End Mills. This proposal has received the approval of the Sub-Committee on Milling Cutters and is now being generally distributed for criticism and comment, after which it will be presented to the joint sponsors. They in turn after approval will transmit it to the A.E.S.C. with the request for designation as a Tentative American Standard.

Machine Tapers. Sub-Committee No. 3 on the Standardization of Machine Tapers is planning to hold a meeting at White Sulphur Springs, May 23 to 26. It is expected that prior to that meeting a Sub-Group will prepare and distribute to the members of the Sub-Committee for study copies of a tentative draft of the first report.

Long-Turn Sprinkler Fittings. During the month of April the vote of the Sub-Committee on Screwed Fittings on the Proposed Standard for Long-Turn Sprinkler Fittings was completed. The standard now goes to the entire membership of the Sectional Committee on the Standardization of Pipe Flanges and Fittings.

Cast-Iron Flanged Fittings. Recently the Sectional Committee on the Standardization of Pipe Flanges and Fittings completed a letter-ballot on the proposed revision of the 1914 Standards for the 125-Lb. and 250-Lb. Cast-Iron Flanges and Flanged Fittings. These standards are accordingly now before the Manufacturers' Standardization Society of the Valve and Fittings Industry, the Heating and Piping Contractors National Association, and The American Society of Mechanical Engineers for approval and transmission to the A.E.S.C.

Screwed Fittings. Three proposed standards for Screwed Fittings are also before the sponsors for the Sectional Committee on the Standardization of Pipe Flanges and Fittings. These cover the dimensions of Cast-Iron Screwed Fittings for 125 and 250 lb. steam pressure and the dimensions for Malleable-Iron Screwed Fittings for 150 lb. steam pressure.

Pipe Threads. The American Society of Mechanical Engineers which is sponsor for the American Standard Pipe Threads is now organizing a Sectional Committee to review this standard in the light of recent developments in the pipe and fitting field. Edwin M. Herr, President, Westinghouse Electric and Manufacturing Company, has agreed to accept Chairmanship of this Sectional Committee.

Gears. Sub-Committee No. 8 on Gear Materials has recently distributed for criticism and comment printer's proofs of a preliminary report on Proposed Specifications for Forged and Rolled Carbon Steel for Gears.

Wrench-Head Bolts and Nuts. This standard is now available in pamphlet form and may be obtained on application to the Publication Sales Department of the A.S.M.E. Price 35 cents.

Small Rivets. The sponsors for the Standardization of Bolt, Nut, and Rivet Proportions, i.e., the S.A.E. and the A.S.M.E., have approved and transmitted the Proposed Standard for Small Rivets to the A.E.S.C. for approval.

Slotted-Head Proportions. A letter ballot of the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions is now in process on the Proposed Standard for Slotted-Head Proportions. Printer's-proof copies of this Standard are now available to those interested on application to the sponsor bodies.

Track Bolts and Nuts. Sub-Committee No. 4 on Track Bolts has recently received a report from the Testing Laboratories of the Pennsylvania Railroad on the 28 specimen bolts which it submitted for check tests. Fourteen of these were heat treated and fourteen were not. All were supplied to the proposed standard dimensions by the Bethlehem Steel Company. A similar set of bolts was prepared by the Buffalo Bolt and Nut Company and tested at the Laboratories of the New York Central Railroad Company. In carrying on this investigation and in developing the standard the Sub-Committee is endeavoring to keep in close touch with the Rail Committee of the American Railway Engineering Association.

Drawings and Drafting-Room Practice. The organization of this Sectional Committee is now complete and the personnel of the five sub-committees has been determined. These Sub-Committees have been appointed to cover the following five parts of the subject:

No. 1, on Specifications for Paper and Cloth, A. A. Coburn, Temporary Chairman

No. 2, on Method of Indicating Dimensions, G. Schobinger, Temporary Chairman

No. 3, on Lettering, T. C. Crawford, Temporary Chairman

No. 4, on Layout, F. G. Wolff, Temporary Chairman

No. 5, on Line Work, S. Ketchum, Temporary Chairman.

Some of these Committees have already held meetings and begun work. It will be recalled that the Society for the Promotion of Engineering Education and the A.S.M.E. are joint sponsors for this project.

Code for Pressure Piping. On April 7 Temporary Chairman Edwin B. Ricketts conferred with the Temporary Chairman of the eight Sub-Committees of the Sectional Committee on a Code for Pressure Piping, and it is expected that meetings of these Sub-Committees will be held in the near future. The following is a list of the Sub-Committees and their Temporary Chairmen:

No. 1, on Plan and Scope, Sabin Crocker, Chairman

No. 2, on Power Piping, John H. Lawrence, Temporary Chairman

No. 3, on Hydraulic Piping, Malcolm Pirnie, Temporary Chairman

No. 4, on Gas and Air Piping, Alfred Iddles, Temporary Chairman

No. 5, on Refrigeration Piping, George A. Horne, Temporary Chairman

No. 6, on Oil Piping, A. D. Sanderson, Temporary Chairman

No. 7, on Piping Materials, F. Hugh Morehead, Temporary Chairman

No. 8, on Fabrication Details, C. G. Spencer, Temporary Chairman.

Standards for Graphic Presentation. The new Sectional Committee on Graphic Presentation is making good progress in the development of this project. Its personnel has been subdivided into six Sub-Committees, and some of them have already held meetings. These Committees are listed below with the names of their Chairman:

No. 1, on Plan and Scope, Ernest F. DuBrul, Chairman

No. 2, on Terminology, M. B. Lane, Chairman

No. 3, on Time Series Charts, Karl Karsten, Chairman

No. 4, on Non-Time Series Charts, W. M. Strong, Chairman

No. 5, on Survey of Current Practice, A. H. Richardson, Chairman

No. 6, on Engineering and Scientific Graphs, W. A. Shewhart, Chairman.

Code for Design of Transmission Shafting[1]

THE volume of material published on the subject of stresses in shafting, the many formulas found based upon different theories of stress, and the general lack of uniformity in definition of quantities and relationships made it necessary for the Sectional Committee on the Standardization of Shafting to review the whole subject of shaft formulas, determine the basic concepts upon which each formula is founded, and select those facts and formulas which in its opinion are scientifically sound. This work was delegated to a sub-committee on the standardization of formulas, the results of whose labors are submitted herewith. It is believed that in the preparation of this report the consideration of no important experimental data which have been published has been omitted.

It has been found necessary to reinterpret some of the results in the light of more recent knowledge of the subject and articulate the facts found by different experimenters. It has also been found necessary to formulate certain definitions which it is hoped will be generally accepted in the interest of clearness of expression.

It is not unlikely that there are omissions and errors in the report. The Committee accordingly invites criticism and comment in order that subsequent printings of this Code may more completely and accurately present this subject.

The Code for the Design of Transmission Shafting covers: (*a*) designing formulas for the cases most frequently met in the design of transmission shafting; and (*b*) diagrams for use in designing shafting.

Appendix A (omitted from this abridgment) covers the various stress conditions that may be set up in a transmission shaft; the various theories of elastic failure evolved from time to time, leading to the many formulas found in engineering literature; the application and limitation of the various theories of elastic failure as applied to ductile ferrous material used in shafts, and the elastic shearing strength of ductile ferrous materials.

Appendix B (also omitted) covers designing stresses, shafting steels, effect of straining action upon working stresses, and the use of constant or base stress with shock and fatigue factors.

A thorough analysis of the three common engineer's theories of elastic failure heretofore advanced, indicates that for all ductile ferrous materials only the one known as the maximum-shear theory is for all practical purposes a true source of elastic failure. Pure-torsion tests made upon very thin tubes seem to indicate that the elastic limit in shear of a ductile ferrous material is practically one-half of its elastic limit in tension.

[1] From report to be submitted at the Spring Meeting, White Sulphur Springs, W. Va., May 23 to 26, 1927, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 29 West 39th St., New York.

It follows also that for uniform stress distribution the working stresses in shear should be taken as one-half of the tensile working stresses. When the stress distribution at any cross-section is widely varying, as in a solid circular shaft subjected to pure torsion, or pure flexure, or combined torsion and flexure, only a small portion of the area is stressed to its maximum value, the inner and less stressed core of the shaft and the mutual lateral restraining effect of the so-called fibers of the material, all tend to reinforce the more highly stressed outer fibers and permit under these conditions the use of a somewhat higher working stress in shear than theory indicates. These matters are dealt with in Appendix A.

The formulas recommended in this report for the design of shafts subjected to torsion or bending only, are based upon the well-recognized common theories of torsion and flexure. For such cases standardization is confined to the adoption of proper unit stresses suited to the material of which the shaft is made and to the operating conditions. For the case of a shaft subjected to torsion combined with flexure or end thrust, or both, no rational method of design has become recognized as standard in the literature of machine design. A thorough analysis of the various engineering theories of design heretofore advanced and their interpretation in the light of more recent knowledge indicates that, under widely ranging conditions of stress, elastic failure in a steel shaft takes place in shear and not in tension or compression; therefore this Code is based on the maximum-shear theory, the most conservative working basis for the design of shafting.

The formulas in the report are perfectly general and apply to all cases of shaft design, even to shafts in special machines. The only limitation imposed is that these formulas provide only for strength and they do not deal with the rigidity or deformation of the shafting system which in special cases such as may come up in machine design, may be the controlling factor. No attempt has been made in the report to cover the field of rigidity or deformation as the scope of the committee's work was limited to designing formulas for transmission-shaft design in which strength and not deformation is the prime factor.

Symbols Employed in Formulas

A = area of cross-section of shaft in square inches
α = ratio of maximum to average intensity of stress, resulting from the axial loading only
D = outside diameter of shaft in inches
D_1 = inside diameter of a hollow shaft in inches
E = modulus of elasticity, approximately 30,000,000 lb. per sq. in.
F = axial tensile or compressive load in pounds
f_c = compressive stress in the material
$K = D_1/D$ = ratio of inside to outside diameter of hollow shaft
K_m = numerical combined shock and fatigue factor to be applied in every case to the computed bending moment
K_t = numerical combined shock and fatigue factor to be applied in every case to the computed moment
l = length of shaft between centers of supports in inches
M = maximum bending moment in inch-pound units
N = revolutions per minute
P = maximum power transmitted by shaft in horsepower
p_s = maximum intensity of the shearing stress in a shaft in pounds per square inch
R = radius of gyration of transverse cross-section of shaft in inches
S = maximum flexural stress, either tension or compression, in pounds per square inch
S_s = maximum permissible torsional shearing stress in pounds per square inch
T = maximum torsional moment in inch-pound units
V = maximum transverse shear in pounds
W = transverse load in pounds supported by shaft
π = constant 3.1416.

Maximum Permissible Working Stresses

For Simple Flexure. The maximum permissible value of the flexural stress, either in tension or compression (S),

= 16,000 lb. per sq. in. for "Commercial Steel" shafting without allowance for keyways
= 12,000 lb. per sq. in. for "Commercial Steel" shafting with allowance for keyways
= 60 per cent of the elastic limit in tension but not more than 36 per cent of the ultimate tensile strength for shafting steel purchased under definite physical specifications.

For Simple Torsion. The maximum permissible torsional shearing stress (S_s)

= 8000 lb. per sq. in. for "Commercial Steel" shafting without allowance for keyways
= 6000 lb. per sq. in. for "Commercial Steel" shafting with allowance for keyways
= 30 per cent of the elastic limit in tension but not more than 18 per cent of the ultimate tensile strength for shafting steel purchased under definite physical specifications.

For Combined Stresses. The maximum permissible intensity of the shearing stress under combined load (p_s)

= 8000 lb. per sq. in. for "Commercial Steel" shafting without allowance for keyways
= 6000 lb. per sq. in. for "Commercial Steel" shafting with allowance for keyways
= 30 per cent of the elastic limit in tension but not more than 18 per cent of the ultimate tensile strength for shafting steel purchased under definite physical specifications.

Shock and Fatigue Factors

K_t = numerical combined shock and fatigue factor to be applied in every case to the computed torsional moment or horsepower
K_m = numerical combined shock and fatigue factor to be applied in every case to the computed bending moment.

Nature of Loading	Values for K_m	Values for K_t
Stationary Shafts:		
Gradually applied load	1.0	1.0
Suddenly applied load	1.5 to 2.0	1.5 to 2.0
Rotating Shafts:		
Gradually applied or steady loads	1.5	1.0
Suddenly applied loads, minor shocks only	1.5 to 2.0	1.0 to 1.5
Suddenly applied loads, heavy shocks	2.0 to 3.0	1.5 to 3.0

Factor for Axial Loading

The maximum stress intensity S resulting from an axial force F is given by the formula

$$S = \alpha \frac{F}{A}$$

where A is the area of cross-section of the shaft and α is a numerical factor.

For axial tensile loads and for those axial compressive loads when the shaft is rigidly supported at frequent intervals so that the shaft acts virtually as a short column, $\alpha = 1$.

For long-column action, l/k less than 115, α should be computed by a long-column formula, one of the straight-line formulas in common use giving

$$\alpha = \frac{1}{1 - 0.0044\ (l/k)}$$

For very long, slender shafts, l/k greater than 115, Euler's formula should be used, which gives

$$\alpha = \frac{f_c l^2}{C\pi^2 E k^2}$$

In the above formulas

α = ratio of maximum stress to average stress
l = unsupported length of shaft in inches
k = least radius of gyration in inches
f_c = compressive yield-point strength of shaft material in pounds per square inch
E = modulus of elasticity of shaft material, for steel approximately 30,000,000 lb. per sq. in.
C = coefficient in Euler's formula; its value for hinged ends is 1, for fixed ends 2.25.

	Values for α					
Slenderness ratio l/k	0	25	50	75	100	115
Value for α	1.00	1.12	1.28	1.49	1.78	2.02

For l/k greater than 115, compute α by Euler's formula.

Design Formulas for Solid and Hollow Shafts

CASE I—GENERAL CASE. SHAFT SUBJECTED TO TORSION, FLEXURE, AND AXIAL LOADING

Diameter of Shaft

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{\left(K_m M + \frac{\alpha F D (1 + K^2)}{8}\right)^2 + (K_t T)^2}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{\left(K_m M + \frac{\alpha F D (1 + K^2)}{8}\right)^2 + \left(\frac{396{,}000\, K_t P}{2\pi N}\right)^2}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

NOTE: All of the stress-ratio formulas discussed under Cases II to VI, inclusive, are derived from these two fundamental relations by the elimination of non-occurring factors.

CASE II—SHAFTS SUBJECTED TO COMBINED TORSION AND BENDING

Solid Circular Shaft

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + (K_t T)^2}}$$

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + \left(\frac{396{,}000\, K_t P}{2\pi N}\right)^2}}$$

Hollow Circular Shaft

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + (K_t T)^2}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + \left(\frac{396{,}000\, K_t P}{2\pi N}\right)^2}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

CASE III—SHAFTS IN PURE TORSION

Solid Circular Shaft

$$K_t T = 0.1963\, S_s D^3$$

$$K_t P = \frac{S_s D^3 N}{321{,}000}$$

$$D = \sqrt[3]{\frac{321{,}000\, K_t P}{S_s N}}$$

Hollow Circular Shaft

$$K_t T = 0.1963\, S_s \frac{(D^4 - D_1^4)}{D} \quad \text{or} \quad 0.1963\, S_s D^3 \sqrt[3]{1 - K^4}$$

$$K_t P = \frac{S_s N (D^4 - D_1^4)}{321{,}000\, D} \quad \text{or} \quad \frac{S_s N D^3}{321{,}000}\sqrt[3]{1 + K^4}$$

$$D = \sqrt[3]{\frac{321{,}000\, K_t P}{S_s N (1 - K_t^4)}} \quad \text{or} \quad \sqrt{\frac{321{,}000\, K_t P}{S_s N}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

CASE IV—SHAFTS SUBJECTED TO BENDING

Solid Circular Shaft

$$K_m M = \frac{\pi}{32} S D^3 \qquad D = \sqrt[3]{\frac{32\, K_m M}{\pi S}}$$

Hollow Circular Shaft

$$K_m M = \frac{\pi}{32}\frac{S(D^4 - D_1^4)}{D} \quad \text{or} \quad \frac{\pi}{32} S D^3 \sqrt[3]{1 - K^4}$$

$$D = \sqrt{\frac{32 K_m M}{\pi S}} \times \frac{1}{\sqrt[3]{1 - K^4}}$$

CASE V—SHAFTS IN BENDING OVER SHORT SPANS WITH HEAVY TRANSVERSE SHEAR

Solid Circular Shaft

$$V = \frac{3\pi S_s D^2}{16}$$

$$D = \sqrt{\frac{16\, V}{3\pi S_s}}$$

Hollow Circular Shaft

$$V = \frac{3\pi S_s (D^4 - D_1^4)(D - D_1)}{16(D^3 - D_1^3)} \quad \text{or} \quad \frac{3\pi S_s D^2 (1 - K^4)(1 - K)}{16(1 - K^3)}$$

$$D = \sqrt{\frac{16\, V}{3\pi S_s}\left(\frac{1 - K^3}{(1 - K^4)(1 - K)}\right)}$$

CASE VI—SHAFTS SUBJECTED TO COMBINED TORSION AND HEAVY TRANSVERSE SHEAR

Solid Circular Shaft

$$p_t = \frac{16T}{\pi D^3} + \frac{16V}{3\pi D^2}$$

Hollow Circular Shaft

$$p_t = \frac{16TD}{\pi(D^4 - D_1^4)} + \frac{16V(D^3 - D_1^3)}{3\pi(D^4 - D_1^4)(D - D_1)}$$

$$= \frac{16\, T}{\pi D^3 (1 - K^4)} + \frac{16 V (1 - K^3)}{3\pi D^2 (1 - K^4)(1 - K)}$$

USE OF DIAGRAMS IN THE SOLUTION OF SHAFTING PROBLEMS—GENERAL STATEMENT

The two general equations of Case I and all others derived therefrom can best be solved by means of two diagrams forming part of the complete Code. In these figures, heavy arcs represent the standard transmission-shafting sizes and lighter lines the standard machinery-shafting sizes. The scale of ordinates represents the values of $K_m M$, or in the most general case the value of $K_m M + \frac{\alpha F D (1 - K^2)}{8}$. The scale of abscissas at the bottom represents the value of $K_t T$ and the one at the top the value of $K_t P$ where P is the horsepower at 100 r.p.m. corresponding to the torque T. These diagrams are applicable to all cases of loading, steady, fluctuating, reversing, gradually or suddenly applied, with minor or heavy shocks, provided correct fatigue factors K_m and K_t are employed.

Both diagrams are based upon a maximum permissible shear stress of 6000 lb. per sq. in. When a shear stress other than 6000 lb. per sq. in. is desired the correct shaft diameter can be obtained by multiplying the shaft diameter selected from the diagram by one of the following factors:

Shearing stress, lb. per sq. in....	4000	5000	6000	7000	8000	9000
Factor.....	1.14	1.06	1.00	0.95	0.91	0.87

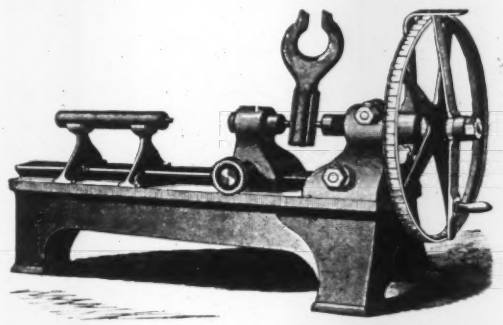
The diagrams give only the diameter of the solid shaft for a given loading. The equivalent diameter of a hollow shaft can be obtained by multiplying the diameter of the solid shaft obtained from the diagram by $\frac{1}{\sqrt[3]{1 - K^4}}$ where K is the ratio of internal to external diameter.

$K = \frac{D_1}{D}$	$\frac{1}{\sqrt[3]{1 - K^4}}$	$\sqrt[3]{1 - K^4}$
0.95	1.75	0.57
0.90	1.43	0.70
0.85	1.28	0.78
0.80	1.19	0.84
0.75	1.14	0.88
0.70	1.10	0.90
0.65	1.07	0.93
0.60	1.05	0.95
0.55	1.03	0.97
0.50	1.02	0.98

John E. Sweet an Early and Ardent Advocate of Accuracy and Standardization in the Machine Shop

FREDERICK A. HALSEY has brought to light a booklet of unusual historical interest to engineers. This booklet, published in 1875 in Ithaca and illustrated by the quaint woodcuts of the period, is devoted to descriptions of the remarkable work then being done in the machine shop of the Sibley College of the Mechanic Arts, Cornell University.

The author was the late John E. Sweet, a Founder and Honorary Member in Perpetuity of the A.S.M.E., who served as master mechanic and director of the machine shop at Cornell University from 1873 until 1878. During that time he not only did splendid work in the advancement of machine-shop practice, but he also trained a group of students in the shop, many of whom became noted engineers themselves in after years. This group of students never forgot their fruitful days in the shop under



THE SWEET MEASURING MACHINE

the kindly professor, and they held reunions with him each year during the twilight of his long and useful life.

Professor Sweet's booklet starts out with a decidedly common-sense chapter of Advice on Bolts and Nuts. This chapter shows that in the middle seventies the machine industry stood on the border line between the era of confusion and the era of standardization. The author says in his introduction—

> In no part of machine-shop practice do the advantages of a uniform standard of sizes show themselves so frequently as in the use of bolts and nuts. The time wasted in an unsuccessful attempt to use a nut of wrong size or pitch, or in trying to find an odd nut to fit an odd bolt, or in going for an extra wrench to turn an old nut, often amounts to far more in value than bolt, nut, and wrench all are worth; and the superintendent of a manufactory who throws all the old bolts, nuts, taps, and dies that are not standard into the scrap heap, and supplies their place by those that are right, makes a paying investment.

The system of bolts and nuts promulgated by the Franklin Institute of Pennsylvania on December 15, 1864, is highly recommended in this chapter. It was through the vigorous efforts of far-sighted engineers like Professor Sweet that the confusion of screw threads in the United States was eventually overcome.

The next chapter is A Description of the Method for Making Frictionless Taps, an article by Professor Sweet reprinted from the *American Artisan*—one of the pioneer journals devoted to machine-shop practice. In this is described an ingenious method of making a tap which will perform according to proper metal-cutting principles. The Sweet plan of tap making of over fifty years ago is quite similar to the most advanced modern plans, and very likely served as a beginning of modern tap-making technique. Professor Sweet found by practical experiments that his scientific tap cut a far better thread with approximately one-half the power needed by the conventional tap of that day.

Following this comes a chapter entitled Description and Illustrations of the Tools of Accuracy Manufactured by the Students and Sold for the Benefit of the Department of Mechanic Arts. Therein are shown standard surface plates, straight edges, angle plates, and a novel design of machinist's square. All of these tools, as indicated by the illustrations, were of neat and scientifically correct design. They were guaranteed to be of extreme accuracy. As a matter of fact, these tools would fit into the lines put out by the present-day manufacturers of such tools.

The most noteworthy chapter in the booklet is one entitled Standard Gauges. This opens with a tribute to the old-time carpenters who, with the wrought-iron square, were able to go into a field of timber and there lay out and frame perfectly a large building. That period, he mentioned, was coincident with that when the two-foot boxwood rule of doubtful accuracy, doubtfully graduated to eighths or possibly to sixteenths of an inch, was the criterion of accuracy in the machine shop. Professor Sweet traces the progress of machine-shop measuring practice from this beginning through the "Bangor scales," which were graduated to sixty-fourths or even to hundredths of an inch, down to the plug and ring gages of Sir Joseph Whitworth, accurate to a thousandth of an inch or less.

Professor Sweet had conceived the idea of manufacturing standard "solid calipers" of sheet steel which would have the accuracy of Whitworth gages but which would be cheap enough to bring them into every-day machine-shop use. To insure the accuracy of these "solid calipers" he designed and built at the Cornell shop in 1874 a remarkable measuring machine.

The Sweet measuring machine had a range of from zero to twelve inches and was graduated in ten-thousandths of an inch. It had a bed similar to a small lathe, except that it was supported on three legs cast integral with the bed. The headstock carried a micrometer screw with buttress threads, 16 to the inch. The thread on the screw and the thread on the nut were of the same length to avoid local wear. Mounted on this screw was an index wheel of large diameter which was divided into 625 parts by lines on the periphery. This gave ten thousand subdivisions on the wheel to each inch of lateral movement of the screw, this being approximately the range of the screw.

The crank by which the screw was turned was not fixed to the wheel, but to a friction bar, the friction being regulated by a central nut so that while there was friction enough to drive the screw, the friction bar would slip as soon as the two feelers came in contact with the work. The index was adjustable to zero and the tailstock was adjusted to full inches by a standard end measuring rods which accompanied the machine. The index arm, which projected over the index wheel, was graduated in ordinary divisions of an inch, eliminating the counting of revolutions. After errors in the machine had been corrected as far as possible, its accuracy was found by careful tests to be within a limit of $^1/_{4480}$ in.

To turn out "solid calipers" on a production basis Professor Sweet also designed and built an ingenious precision grinding machine for bringing them to exact size. This was one of the earliest universal grinders and was capable of very fine work both on flat and cylindrical surfaces. Cylindrical work was ground between dead centers to insure absolute concentricity. The internal faces of the calipers were ground in this machine by holding them upon a yoke hung upon the main centers, the micrometer screw in the tailstock and a spring headstock center enabling the operator to give the caliper delicate lateral motion to insure perfect accuracy.

Professor Sweet's project for manufacturing gages for the trade at the Cornell shop did not materialize to any great extent, because he left the University before it had fully developed. The work he did, however, had a great influence upon the progress of interchangeable manufacturing in the United States. Both his measuring machine and his gage grinder were extensively copied by commercial gage makers, and some of their features are still evident in modern designs of machines of such types.

Mr. Halsey, a student under Professor Sweet and very close to his pioneer gage work, and later an engineering editor and recognized authority on machine-shop practice, has had an unusual opportunity to pass sound judgment upon the importance of it. He sums up his opinion, in his book Methods of Machine Shop Work, by saying, "The beginning of accurate shop measurements in the United States was by Dr. John E. Sweet at Cornell University."

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or . . . . . printed in its publications (B2, Par. 3).

Coöperation and Specialists

IT IS NOT difficult for any craft or profession to show how industry and world progress in general would be completely crippled if suddenly deprived of its special contributions. This is only another way of proving that in our complex civilization even specialists are interdependent, and the individual who disregards that fact and refuses coöperation speedily suffers divers punishments.

The close relationship between the mechanical engineer and the chemist in industry affords an excellent illustration of the points we have in mind. We have known engineers who were prone to disregard chemistry, had no comprehension of its bearing upon their work, and only with difficulty were able to distinguish between the research laboratory and the corner drugstore. The failure of a carefully designed piece of apparatus from chemical causes which might have been avoided taught a costly but well-remembered lesson. Similarly, chemists have been known to fail in a piece of important work for lack of understanding of simple yet fundamental mechanical principles. Some of them have looked upon the engineers as merely the mechanics of science, forgetting that in not a few instances they have played important roles in laying out the work.

The success met in the liquefaction of coal depended in a large degree upon correct mechanical design and construction. To be sure, the chemistry of the reaction had to be thoroughly understood first. But it could not be conducted on even the laboratory, let alone the commercial, scale without reaction chambers, valves, and what not, especially designed for the purpose. The increasing importance of chemical reactions at high temperatures and pressures means closer attention in the chemical industry to strictly engineering factors.

The points of view and habits of thought required for creative work in specialties differing as do chemistry and mechanical engineering are seldom found in a single individual. We believe, therefore, that close coöperation between specialists is to be urged, rather than that any man should attempt to be all things to all work. To this end national conferences would be helpful, the purpose being to exchange information on developments which demand concurrent progress and to promote a better understanding of each other's work. We believe that such gatherings should take the form of symposia arranged officially by the national societies whose members are involved, in each case, rather than that one group should frankly invade the field of another and endeavor to carry out a program with the aid of individuals as contrasted with official coöperation. Programs should be constructed to achieve a definite and limited purpose. Men recognized as authorities should be chosen in each case to present the discussion, and careful plans laid for the development of the argument following initial presentation.

This has often been called the age of specialists, but the most successful are those who pay careful attention to the relationship between their work and that of other specialists.

H. E. HOWE.[1]

Better Teachers

EVERY teacher of engineering subjects is faced from time to time, if not continually, with the problem of keeping abreast of progress. He may read extensively the literature of his profession as it comes to him in magazines, proceedings of societies, pamphlets, catalogs, and books; he may make extensive excursions to industrial plants and engineering projects; he may ally himself to some firm of engineers as a consultant or worker during academic recesses; he may serve on committees of research or standardization; he may be engaged in research in his university's laboratories; he may spend his vacations in some of the excellent industrial courses offered for such men by the larger manufacturing organizations; but however he may accomplish it, the true teacher must increase his knowledge and stimulate his enthusiasms in one or many ways if he is to be more than a drudge and if he is to teach with inspiration.

The summer school under the auspices of the Society for the Promotion of Engineering Education, announced elsewhere in this issue, will offer the opportunity which many a young man has been looking for, and those who avail themselves of it will carry back to their universities an increased purpose, a greater enthusiasm, a confidence in themselves which may save them from the ever-present danger of mediocrity in a profession in which there are too many mediocre men.

Because his work is largely in the repetition of lessons which, except for details, vary little from year to year, the teacher is likely to become merely a transmitting agency, whereas he should become a producing agency. The mind which is filled with the products of research, for instance, is much more keenly alive to the significance of the fundamentals of science, and has a broader field of experience from which to supply the convincing proof, than the mind grown stale with repetition of a meager text. Inspiration for teaching comes from being so full of the subject that it must come out, regardless of natural gifts for imparting knowledge; it comes from action, study, research, production, rather than from being a good fellow with some popularity among the students and an interest in young men.

But at this point objections are likely to be raised by the teacher that his opportunities are limited by time, income, equipment, expense. There is much justice in these objections. A man who teaches eight hours a day has little time for further work unless he has unusual strength; young instructors with families to support most frequently think more of money than of experience; few educational institutions have adequate equipment or personnel for elaborate or extensive engineering researches; and because of their very nature, these researches are so expensive that only wealthy industrial organizations can afford to underwrite them. A sympathetic and far-seeing university administration, however, will not wish to lose its best men and will offer as few obstacles as it can to their development, and the persistent seeker for truth will not suffer himself to be denied by lean fortune.

The blame for mediocre teachers rests on many shoulders: on those of the teacher principally, on those of the university administration, and on those of industry. Let each man examine the question personally. Teachers, are you hiding behind excuses? Administrators, are you failing to develop the potentialities of your faculty members? Industrialists, are you withholding your coöperation and then grumbling at the educational system?

[1] Editor, *Industrial and Engineering Chemistry*, Washington, D. C.

Expanding the A.S.M.E. Publications

Council, in Furtherance of Its New Policy, Approves of Recommendations in Report of the Society's Standing Committee on Publications and a Specially Appointed Advisory Committee

DURING the past few years the technical activities of the Society have grown rapidly, the quality of papers presented has improved, and the quantity has increased. These changes have produced a gratifying increase in the volume of papers that require publication and have demanded a rapid expansion of Society publications. The new Professional Divisions have stimulated public discussion of engineering papers. These Divisions are now just making a good start. Their opportunity is in the future.

To increase the service of the Society to the specialist, as well as to the general consulting engineer, to publish properly the rapidly increasing number of good papers presented, and to render this additional service without additional cost is a problem of the greatest importance.

Purpose of Changes

This new growth in the Society has brought new problems, the most pressing of which relates to Transactions. This publication is continually growing more bulky and varied, but at the same time it is far less complete than it was in former years. In accordance with our present practice it is reserved for material of value for permanent record. Much of the material we are forced to omit from it is at least of equal worth with that formerly accepted. Transactions can no longer fulfil its function satisfactorily, and it seems clear that more adequate means must be provided if the membership is to be properly served.

The second problem relates to the need for strengthening the Professional Divisions, and through them meeting the requirements of the specialists in our membership as is not now possible. The specialist in, for instance, fuels or aeronautics, at present receives only a part of his papers in permanent form in Transactions. Other material of interest to him is available only in Mechanical Engineering, and often in abridged form at that, and valuable discussion is separated from the text of the papers. It is proposed to publish the papers and discussions of a given Professional Division complete and bound together. This will at one stroke put them in reference form for the specialist; and furnish a complete written and satisfying record of the work of the Professional Divisions as well.

The publications that are not affected, or affected only in a minor way, are: Condensed Catalogs, Engineering Index, The Year Book, and the *News*.

Transactions. It is proposed that Transactions shall become a record of the Society's activities and a thorough index of all its publications, rather than remain a rather drastic selection and condensation of the papers presented to it.

Transactions will contain a portrait of the President, a list of officers and committees, reports of committees and of the business meeting, the Presidential address, a list of Past-Presidents and Honorary Members, an index (with notes) of all reports of technical committees and of all papers presented at authorized meetings, whether Annual, Spring, Divisional, Regional, or Local, and a statement of the form and place in which these papers are published, if at all; a necrology, the constitution, by-laws, and rules, and a calendar of meetings, Society, Divisional, and Local.

Method of Publishing Papers. In addition to the above there will be a group of four classes of publications which will be correlated in form and make-up. This group will consist of

1 Mechanical Engineering
2 Preprints of papers prior to presentation at meetings
3 Papers, with discussions, which constitute the final record
4 Quarterlies for each of the Professional Divisions.

All of these will approximate the $8\frac{1}{2} \times 11$-in. size so that they will file with the standard letter sheet. They will all be perforated for filing in standard binders, including, if possible, the text pages of Mechanical Engineering. If this is not found possible, they will be marked for punching. By this means any technical information published by the Society can be filed in binders or in filing jackets or in any way desired by the member. This goes part way at least toward meeting the Local Sections delegates' suggestion for loose-leaf data. It will enable each member to build up a technical record from the Society's publications in the precise form best adapted to suit his needs. This is the prime improvement in the service to the membership contemplated by the proposed changes, as such filing and binding is at present impossible, and Transactions as at present published does not serve its original purpose.

"Mechanical Engineering." This will retain its present complexion and trend of development, except that it will select for full publication only those papers which will serve to make it the best-rounded-out, most interesting, and most useful engineering journal in existence. Synopses of papers appearing in the Divisional quarterlies will be included. This publication will meet the general engineering needs of the membership, leaving the Quarterlies (see below) to satisfy the specialist.

Preprints. These will be preprints of the papers. They will be punched for filing, and will be distributed before the meetings on request. Suitable request forms will be printed in the *A.S.M.E. News*.

Papers, with Discussions. This will be the final form of the papers. They will have the same make-up as the Preprints and Mechanical Engineering, and will come punched.

Professional Division Quarterlies. All edited papers presented before each Professional Division will be bound together and mailed quarterly to the membership of that Division. There may be added to these papers a report of the meetings, other technical matter, and a record of the organization of the Division. Advertising will not be carried. These Professional Division Quarterlies will be punched for filing.

Complete Papers Bound. In addition, it is planned to have about 750 complete sets of papers bound and distributed to designated depositories throughout the world. A limited number will be available for sale to libraries, individuals, etc.

Distribution of the Publications

The *News*, Condensed Catalogs, and Mechanical Engineering will be sent to the full membership as at present. The Year Book will be sent on request as at present. The preprints will be distributed by the author and the Meetings Committee to assist in working up discussion of papers. They will also be freely furnished on request to any interested member.

The quarterlies and papers will be distributed on the basis of Professional Divisions registration. Every member will be required to select and to register in one Professional Division, and will thereupon receive automatically and freely all the edited papers of that division in quarterly form. In addition he may order any edited paper whatsoever presented by any other Division. There is no restriction on this. The whole body of papers is free to the whole membership, in convenient form for binding in any desired personal indexing plan. The budget presented by the Publications Committee calls for the furnishing of 70 per cent more material than ever before. The whole program is one of expansion and more complete service.

In addition to this increased personal service, it is hoped that these changes will assist the Professional Divisions to a fuller self-expression; increase the scope and importance of their activities; forestall the further subdivisions of engineering associations into disconnected fractions; facilitate the amalgamation with us of fractions at present separated; and in general increase the range, importance, and usefulness of the Society's activities.

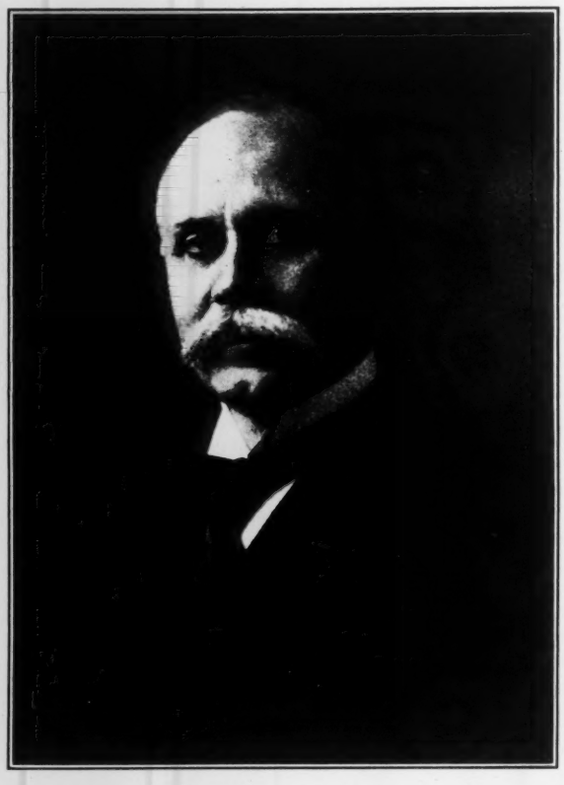
[Realizing the importance of a new publication policy, the Publications Committee in December, 1926, asked the Council of the Society to appoint a special Advisory Committee to sit in with it to discuss the problems involved, and their foregoing report is now open to public discussion and will be presented at the White Sulphur Springs Meeting for further consideration.]

Jesse Merrick Smith Dies

Twenty-Eighth President of the A.S.M.E. Passes Away in New York at Age of Seventy-Eight

JESSE MERRICK SMITH, retired consulting engineer and President of The American Society of Mechanical Engineers in 1909, passed away on April 1 at his home in New York City, at the age of seventy-eight. He joined the Society in 1883 and served as Manager from 1891 to 1894, as Vice-President from 1894 to 1896 and from 1899 to 1901, and on the Council under the presidencies of Hunt, Loring, Cox, Davis, Billings, Fritz, Melville, Morgan, and Wellman.

Jesse Merrick Smith was born in Newark, Ohio, October 30, 1848, the son of Henry and Lucinda Salisbury Smith. After studying at Philo Patterson's School in Detroit, he entered the Rensselaer Polytechnic Institute at Troy, New York, in 1865, and from there went to the Ecole Centrale des Arts et Manufactures, Paris, receiving the M.E. degree in 1872. On his return to the United States he entered professional work in the Hocking Valley, Ohio, building blast furnaces and coal mines. He remained at this work until 1880, at which time he opened a consulting engineering office in Detroit, Michigan, and devoted his time to designing special machinery as well as manufacturing and power plants in connection with manufacturing establishments.



JESSE MERRICK SMITH

During the latter part of his consulting work in Detroit he entered the field of patent litigation and became an expert in a number of important suits. In 1898 he moved from Detroit to New York, in which city he opened an office as a consulting engineer and expert in patent litigation.

Mr. Smith became President of The American Society of Mechanical Engineers in 1909, and as representative of the Society took an important part in the dedication of the Russell Sage Laboratory of Mechanical and Electrical Engineering at the Rensselaer Polytechnic Institute.

Mr. Smith was a charter member of the American Institute of Electrical Engineers, and for many years was a member of the American Institute of Mining and Metallurgical Engineers. He was president of the American branch of the Alumni of the Ecole Centrale. As a graduate of this celebrated school he became a member of the Société des Ingénieurs Civils de France.

Mr. Smith was a very active member of the A.S.M.E., and participated in several of its conventions with the foreign engineers in Europe and represented it at many international meetings. During his connection with the Society he was closely identified with the development of the Constitution and By-Laws and the fundamental principles of present-day Society activities. It was during his connection with the Council and under his presidency that the Local Sections of the Society were developed. Starting with the organization of a section in Milwaukee, the section established in St. Louis in 1909 was followed by one in Philadelphia in 1912 and another in St. Paul in 1913. The importance of the local-section movement indicates very clearly the breadth of vision of Mr. Smith and his associates.

In 1916 Mr. Smith married Miss Mabel A. McKinney, of Brooklyn. Mr. and Mrs. Smith traveled extensively during the last eight years, spending much time in Europe. During this residence abroad Mr. Smith represented American engineers at many conferences and engineering celebrations.

With all of his work in connection with the Society, nothing was too great to be done if by the doing accuracy and justice could result from the action. In all dealings Mr. Smith was motivated by the right at any cost. His legal training was of great service in connection with the Constitution and By-Laws, and his broad acquaintance added much to the prestige of the Society during his membership on the Council.—A. M. G., JR.

Funeral services for Mr. Smith were held at his home on Park Avenue, New York, on April 5, Dr. Howard Duffield, Pastor of the First Presbyterian Church, officiating. Seventeen Past-Presidents of the Society served as honorary pallbearers, namely, Worcester R. Warner, Ambrose Swasey, John R. Freeman, Alex. C. Humphreys, Dr. W. F. M. Goss, James Hartness, Dr. D. S. Jacobus, Dr. Ira N. Hollis, Charles T. Main, M. E. Cooley, Major Fred J. Miller, Edwin S. Carman, Dean Dexter S. Kimball, John L. Harrington, Fred R. Low, Dr. W. F. Durand, and W. L. Abbott. The official representatives of the Society at the funeral included: President Charles M. Schwab, Col. C. H. Crawford, Dr. D. S. Jacobus, Dean Arthur M. Greene, Jr., L. P. Alford, Dr. Fred R. Low, Dr. W. F. M. Goss, Calvin W. Rice, Jas. E. Sague, H. H. Barnes, W. M. McFarland, H. F. J. Porter, and H. de B. Parsons.

Mr. Smith's passing occurred while the Kansas City Meeting was in session, and the Council, upon being apprized of the sad event, passed the following resolutions:

Resolved, That in the passing of Jesse Merrick Smith the Council is deeply sensible of the loss of a member long remarkable for his devotion to the Society, and of his service of many years in the development of the Constitution and By-Laws, in the establishment of the Local Sections, and in the development of the fundamental policies of the Society.

Resolved, That the President and Secretary be requested to send a copy of these resolutions to Mrs. Smith, and that it appear in the Society's publications.

The following letters of appreciation from fellow-members and associates of long standing have been received.

Few men who have been honored with the presidency of The American Society of Mechanical Engineers have served as intelligently and as effectively as Jesse Merrick Smith. His interest in the Society was deep and constructive, and his contribution to the structure of its by-laws and procedure will remain as a memorial of his labors.

We had been very close friends for these many years, beginning with our trip to Europe with the party of American engineers in 1889. Since then we have traveled together in many lands. His mind was keen and analytical, and his interest in a wide variety of subjects so intelligent and well informed as to make him what he always was, an entertaining and stimulating companion.

In the design of intricate, special machines he was exceedingly successful. His knowledge of the mechanic arts, acquired by many years of study and work in our country and abroad, was extensive, and his familiarity with American patents and patent law was so well recognized as to lead to frequent demand for his services in an expert capacity.

Under a quiet exterior he carried a loyal spirit and strong purpose, and in the highest sense of the word he was a gentleman. His loss is indeed a sad one to me and his other close friends, and his counsel and helpfulness will be greatly missed in the organizations to which he so freely gave his time and services.

AMBROSE SWASEY.

During my long acquaintance with Jesse M. Smith, I found him to be a man of sterling character whose motives and actions were based on high ideals. His interest in the A.S.M.E. never lagged, and his advice and

counsel were always based on the thought that the Society should never lower its standards, and that its traditions should be sacredly maintained. He was a sane and valuable counselor at all times. I have held my personal friendship with him in high esteem.

CHARLES T. MAIN.

I knew Jesse Smith only by my contacts with him in connection with the affairs of the Society.

He always stood steadfastly for what he believed to be right, and was willing and able to take infinite pains to determine, for himself, what was right.

As a member of the Council and as President of the Society, he was, first of all, thoroughly conscientious and painstaking in discharging every responsibility. No one, I think, could doubt his entire sincerity, even though one might, upon occasion, differ with him on matters of policy.

Under a placid and uncommonly calm exterior he possessed, nevertheless, an unusually strong emotional nature; he was a faithful and devoted friend, clean minded, well educated, and trained in his profession, had traveled much abroad, and was altogether a good and highly useful citizen.

FRED J. MILLER.

The American Society of Mechanical Engineers has suffered a great loss in the death of Jesse Merrick Smith. He was devoted to the Society and took the deepest interest in promoting its welfare and advancing its ideals. Mr. Smith was one—unfortunately there are too few—who regarded engineering as a profession of the highest grade; who upheld its principle of ethics, and who always appreciated the accomplishments of others. Mr. Smith had a clear insight into matters which were brought to his attention, and logically separated the right from the wrong. His friends were many, and they feel his loss to the profession.

H. DE B. PARSONS.

In the death of Past-President Jesse M. Smith the A.S.M.E. has lost a most enthusiastic and valuable member. His record as an engineer and his service to our Society covering a long period of years are an inspiration to those of us left behind. They should be splendid incentives for the younger man. He was a most loyal friend and his death makes a sad break in the ranks of the older members of our Society.

I. E. MOULTROP.

The success of the Society in increasing progressively is due not only to the participation of the new members, but to the devotion and untiring efforts of those who, like Mr. Jesse Merrick Smith, have been with the Society from its very beginning and unremittingly serve the profession through the Society's several activities.

From 1883 when he was among the earliest group to work for the Society and to the very end, Mr. Smith served with enthusiasm. Only last summer he helped organize the members of the Society who are residing in France to form an association with the members of the other national engineering societies of the United States so that not only professionally, but socially, the members of these respective societies might derive the full benefits from their membership. Correspondingly, Mr. Smith received great pleasure out of this investment of his time and thought.

The Society owes a real debt of gratitude to Mr. Smith for his fifty years of continuous devotion.

CALVIN W. RICE.

The Mid-May Issue

A SPECIAL White Sulphur Springs issue of MECHANICAL ENGINEERING will be mailed to the members on May 10. It will contain the papers that form a part of the technical program of the Spring Meeting to be held at White Sulphur Springs from May 23 through 26.

This special issue will reach members of the Society well before the Meeting, and will enable them to participate in the discussion of the excellent papers to be presented. The coming Spring Meeting is the first A.S.M.E. gathering to be held at a resort since 1910, and the interest that is being aroused in the entertainment events alone insures a goodly attendance. Every one is going to enjoy the scenery, the outdoor recreation, and the excellent technical program.

International Critical Tables

ONE of the major projects of the National Research Council has been the preparation and publication of International Critical Tables of Numerical Data in Physics, Chemistry, and Technology, undertaken at the request of the International Union of Pure and Applied Chemistry and the International Research Council. The work of critical compilation began in 1922, and the first of the projected five large volumes was published in 1926. The responsibility for the editorial work has rested on Dr. E. W. Washburn, editor in chief; Dr. Clarence J. West, associate editor for chemistry; Dr. N. Ernst Dorsey, associate editor for physics; and Dr. F. R. Bichowsky and Dr. Alfons Klemenc, assistant editors. These responsible editors were assisted by an advisory editorial board composed of seven eminent chemists and physicists, and by ten corresponding editors and about 300 coöperating experts. The data used are derived from material in eighteen languages.

Nearly $200,000 has been expended on the compilation. This money has come as gifts from 244 firms and individuals and two major foundations (Carnegie Corporation and International Education Board.) The gifts from these foundations, amounting to $70,000, were made for the special purpose of enabling the published tables to be sold at a price not prohibitive to individual buyers. Publication was undertaken by the McGraw-Hill Book Company, Inc.

The regular price for a set of five volumes was fixed at $60 but a pre-publication price of $35 a set was made to all subscribers ordering sets before the actual publication of Volume I. Some 6600 sets have been ordered at the pre-publication price of $35, and several hundred sets at the post-publication price of $60 a set. Volume I may be consulted in the United Engineering Societies Library.

Ask Me Another!!

THOMAS A. EDISON provided a seven days' wonder a few years ago by making public a long list of questions he used to test the general information of applicants for employment in his laboratory. These questions aroused a large amount of public discussion and stimulated editorial comment in the daily press concerning everything from abaca to zymosis, but after their brief hour expired, they disappeared. Now a new fad is in the ascendancy. Children and grown-ups are abandoning kissing games at their parties and are taking up this questioning operation. Books of questions are being published feverishly at the rate of one a week. People are studying the questions assiduously in the hope of thus acquiring a liberal education in the shortest possible time. One technical paper is reported to be using this method to drive home some of the fundamentals of the field it covers. Engineering is touched on in the new books of questions, but of course only in a general way. Obviously MECHANICAL ENGINEERING should have a part in this move for a better-educated public, and accordingly it presents the following questions for mechanical engineers to ponder over:

1. Who was Newcomen?
2. Give within five years the year when Watt built his first steam engine.
3. For what was Maudsley noted?
4. What past-president of the A.S.M.E. wrote a famous treatise on cutting metals?
5. What American inventor tried to build a submarine for Napoleon?
6. Within two years, state when the first locomotive was operated in America? The first steam engine?
7. What famous British pioneer in railway transportation had a son famous in bridge building?
8. Who invented the first steam hammer? Did he build it?
9. What was the "cheese box on the raft?" Who designed it?
10. What past-president of the A.S.M.E. had a reputation as an Arctic explorer?
11. What is the American Engineering Council?
12. What is the size of the largest steam turbine operating now? In process of construction?
13. Although widely known as the inventor of the cotton gin, in what way did Eli Whitney exert a tremendous influence upon American manufacturing methods?
14. What famous British general balked the united efforts of Nasmyth, Whitworth, and other influential British Engineers to introduce interchangeable manufacture in English arsenals?

Kansas City Regional Meeting

Three-Day Meeting Marked by Excellent Attendance and Lively Interest in Technical and Educational Sessions—Entertainment Events and Inspection Tours Well Planned and Executed

ANOTHER of the Society's Regional Meetings has passed into history, and with it have gone more of the old, time-worn impressions of the Middle West. Those who, jokingly of course, once held that the vast farm lands and the rustics who inhabited them represented the activity and thought of that section, can no longer have their little joke. One cannot imagine a more typically mid-western city than Kansas City, yet it would indeed be difficult to find a more representative group of engineers than those who spent the three days April 4, 5, and 6 among the people who have a reputation for demanding to be "shown." In this case, however, they reversed the proceedings and demanded that they be allowed to show.

The local committees had been exceedingly active, with the result that a well-balanced program of both technical and entertainment events was carried out without a hitch. Headquarters were established in the Baltimore Hotel. The first day was devoted to registration, the Council meeting, and the session on Education and Training for the Industries. In the evening both ladies and gentlemen enjoyed a splendid dinner, at which no one was asked to make a speech, and following which a very persuasive orchestra called those who could leave their cigars and gossip for awhile to the dance floor. Tours of inspection followed the technical sessions of Tuesday. The ladies during the morning visited the Loose-Wiles Biscuit Co., where they learned how to bake on a large scale. A matinee filled their afternoon. The men inspected the Northeast Station of the Kansas City Power and Light Company, the North Kansas City water-works plant, the Standard Oil Company's Sugar Creek refinery, the Sheffield Steel Company's plant, and the American Radiator plant. A banquet at the Baltimore Hotel in the evening, following which there were short talks from past-presidents and members of the Council, closed the day's activities. The technical sessions closed at noon on Wednesday, allowing those who would to take advantage of a very delightful tour of the city's beautiful parks and residential sections.

Session on Education and Training for the Industries

The session on Education and Training for the Industries, held under the auspices of the Committee on Education and Training for the Industries, was the first to get under way. It was called to order at 2:00 p.m. on Monday, April 4, with Prof. Wm. T. Magruder, Vice-President of the Society, in the chair. The first paper, Railway Apprenticeship in a National Apprenticeship Plan, was presented by the author, F. W. Thomas. Following this paper, L. A. Hartley presented one entitled, Industrial Problems or Difficulties—A True Basis for the Development of Foremen. The final paper was by Dean P. F. Walker, who discussed Education for the Industries. The keen interest in the general subject was well illustrated by the great amount of discussion offered. One left the meeting with a well-formed impression that if we are to carry on in industry in the years to come more actively than we have in the past, some means must be worked out to supply leaders to take the places of those now in harness—men who can carry the burdens further and better.

Petroleum Session

The Petroleum Session, held under the auspices of the Petroleum Division, convened at 9:00 o'clock on the morning of April 5, with W. G. Heltzell, Vice-Chairman of the Division, in the chair. Three papers were presented at this session, as follows: Drilling and Pumping-Rig Equipment, by Glenver McConnell; Electrical Applications in the Oil Fields, by D. M. McCargar; and Lubrication of Diesel Engines, Correct and Incorrect Methods of Oil Application, by W. O. Northcutt. Mr. McConnell's paper was discussed at some length by Hollis P. Porter, who mentioned some of the principal points to be remembered in the design of new equipment. Reference was also made to the increasing use of rotary drilling equipment for deep wells.

Considerable discussion was offered on Mr. Northcutt's paper also. J. H. Galloway referred to the splash system of lubrication, and the recent tendencies as regards piston-ring design. S. A. Hadley discussed some of the types of lubricators available, the effect of temperature on wear, and the effect of charred or unburned fuel on the life of equipment. F. I. Kemp mentioned the effect of temperature on wear. J. J. Stines felt that many troubles for which the oil filter and general oil conditions were responsible were often charged to the lubricating system. The importance of selecting a good grade of oil was emphasized by Carl L. Johnson.

Management Session

Three papers were presented at the Management Session, held on the morning of April 5. The session was conducted under the auspices of the Management Division of the Society, and was presided over by Dean P. F. Walker of the School of Engineering of the University of Kansas. James McQueeney was first on the program, with a paper on Industrial Management, in which he traced the development of manufacturing methods in a large baking establishment. The second paper was by Wm. R. Harrison, and discussed the Management of Railway Shops and Terminals. The manifold operations necessary to keep equipment operating at maximum efficiency were described. In the discussion B. P. Phelps, William Elmer, and Roy V. Wright referred to the desirability of speeding up operations, the necessity for checking up on the workmen, methods of handling hot boxes, and the part management has played in reducing or eliminating congestion. The final paper of the session was on Personnel Administration in the Steel Industry, and was presented by the author, F. V. Larkin. Mr. Larkin indicated the scope of personnel administration as it exists today, and reviewed briefly the history of the steel industry since the introduction of personnel administration. In the discussion which followed, F. G. Buffe mentioned the human element that must be considered in the industrial problem, and described some ways in which the Kansas City Public Service Co. had approached it. Forest E. Jones also touched upon relations between company and employee. Howard A. Fitch submitted a written discussion in which he deplored the too frequent tendency on the part of the management to introduce a flavor of philanthropy.

Power Session

Vice-President A. G. Christie presided at the Power Session, held under the auspices of the Power Division, which convened at 9:00 o'clock on Tuesday morning. Two papers were presented at this session, following which there was a Symposium on Steam-Power Plant Development in the Middle West. The first paper, Treatment of Feedwater for Industrial and Power-Plant Boilers, was presented by S. T. Powell, who discussed methods of removal of suspended and soluble solids, and the removal of gases. The several types of equipment required for this work were described. A written discussion submitted by F. H. Thorne described experiments with sodium aluminate in softening equipment. The paper on Present Tendencies of Steam-Station Design, by V. E. Alden, described some of the changes which have taken place in recent years to increase the efficiencies of power plants. It also described the latest installation of the mercury-vapor turbine. Written discussions were offered by E. H. Tenney, J. A. Keeth, and F. S. Collings. Unfortunately, space does not permit abstracting these discussions here, but they will appear in Mechanical Engineering at a later date. In the symposium following the papers, the following contributions were presented: Operation Problems Encountered in Boiler Operation in Omaha, by Charles F. Turner; The Use of Pulverized Fuel at the Big Sioux Station of the Sioux City Gas and Electric Company, by K. M. Irwin; Development of Steam Stations in the Middle West, by C. S. Tomlinson; and Pulverized Coal in the Middle West, by E. H. Tenney. An account of the symposium will appear in an early issue of Mechanical Engineering.

LECTURE BY HEAD OF KANSAS CITY CHAMBER OF COMMERCE

Following the adjournment of the three simultaneous sessions of Tuesday morning, those in attendance enjoyed a lecture by Lou Holland, president of the Kansas City Chamber of Commerce. Mr. Holland traced the industrial development of the country from the early days of crude methods and equipment down to the present era of specialization and concentration of effort, giving particular attention to the place of the engineer in this program. He then described the growth of industry in Kansas City and explained the attitude of the Chamber of Commerce toward new industries, laying particular stress on the fact that there was no desire to attract new industries unless they were convinced that it was to their advantage to locate in the city; they must see whatever advantages existed and make the selection without being urged.

FUELS SESSION

The fuel experts had their inning on Wednesday morning in the Fuels Session, presided over by James Van Brunt, Chairman of the Fuels Division, under the auspices of which the session was held. Four papers were presented, as follows: Low-Temperature Distillation, by Walter Runge; Burning of Mid-Western Fuels, by E. L. McDonald; Industrial-Furnace Fundamentals, by Victor J. Azbe; and Production and Distribution of Fuel, by C. M. Young. Dr. Runge's paper was presented by R. P. Soule. Several slides were shown and fuel samples exhibited. Considerable interest was manifested, and the discussion, both written and oral, added much to the value of the paper. Those offering comment were H. G. Nevitt, Wm. L. Abbott, Victor J. Azbe, and A. G. Christie, and the several points touched upon were the origin of the coal mentioned in the paper, readiness with which coke from which volatile matter had been removed would ignite, the flowing qualities of coal, etc. The subject of Mr. McDonald's paper came very close to the heart of the engineer of the Mid-West, as was indicated by the extent to which it was discussed from the floor. Insufficient space is available to present the substance of the discussion at this time, but a complete account will be published later in MECHANICAL ENGINEERING. The papers by Azbe and Young also created considerable interest, and the discussion following their presentation proved valuable.

KANSAS CITY SESSION

The Kansas City Local Section made its contribution on Wednesday morning in the form of a session dealing with flour mills, grain elevators, and agricultural machinery. F. S. Dewey, Chairman of the Kansas City Section, presided. The first paper on the program was Protection of Flour Mills and Grain Elevators Against Fire and Explosions, by F. D. Hoxie. This was followed by Mechanical Engineering in the Flour Milling Industry, by M. D. Bell. The final contribution was by O. B. Zimmerman who discussed Some Applications of Machinery as Applied to Agriculture. Mr. Hoxie's paper described some of the precautionary measures that had been adopted in elevator construction to minimize damage when an explosion occurred in spite of the care exercised in daily operation. Mr. Bell told his hearers of the part played by the mechanical engineer in the development of the great milling industry of today. Considerable information was disclosed in the paper by Mr. Zimmerman who described several new types of labor-saving devices designed to produce greater yield per man employed in agricultural work. He also described the mechanical aids being used in the eternal war on insect pests, mentioning particularly the corn borer, which is being attacked through the medium of the ensilage cutter. He also described machinery for plant dusting, and the use of the airplane for large-scale dusting, such as orchards, etc. Considerable discussion followed each of the papers.

Notes on Engineering Education

A New Course in Fuel Engineering

THE Mechanical Engineering Department of the Towne Scientific School, University of Pennsylvania, announces the opening, in September, 1927, of a new one-year course in fuel engineering, leading to the degree of Master of Science in Fuel Engineering.

This course, according to the prospectus, "is intended primarily for those who have had the advantage of a complete undergraduate education of college grade and who have also had a practical experience in fields allied to fuel engineering." This raises the course to the dignity of graduate study, the requirements for admission being practically the equivalent of those for other courses leading to the Master of Science degree. In order to provide for those who may not desire the complete course but who may be qualified in parts of the work offered, special students may, with the approval of the director, be admitted as "auditors."

The classes are to be conducted by Prof. Robert H. Fernald, Director of the Mechanical Engineering Department, Towne Scientific School, University of Pennsylvania, and other members of the faculty of the University, and by engineers of recognized standing in the fields covered by the course who will deliver special lectures; in all, a faculty of 51 men of prominence in the profession.

A comprehensive survey of the course shows the breadth of its curriculum: fuel resources; mining methods, preparation for market, distribution, storage and rehandling; composition and combustion of fuel; manufacture of special fuels; uses of fuels and specifications for purchase; furnaces; fuel sampling, analysis, and calorimetry; fuel testing in heat and power appliances, domestic heating; cooking; smoke elimination; regulations affecting use of water-power and fuel resources; research; electives. A study of the prospectus indicates that in many branches of the course considerable attention is paid to field work, such as in visits to mines, power plants, coking and gas plants, etc. Other features are the opportunities given for actual laboratory work and for research in special problems assigned for thesis work. It is also gratifying to note the liberal allowance of time (seven out of thirty hours per week), devoted to electives, which may be studied in any of the several departments of the University. The individual, the University, and the profession will benefit from this wise inclusion of opportunities for broad educational improvement.

The University of Pennsylvania deserves well of the engineering profession in establishing this well-planned course with its distinguished faculty. There are many industries throughout the country which could realize a substantial profit by making it possible for some of their young engineers to take this course. Fuel engineering becomes increasingly a highly specialized and technical study, and its future development will be more rapidly advanced by engineers who have had the training the University of Pennsylvania is prepared to give than by these same men with unawakened imaginations groping in the narrow paths of self-education.

A Summer School for Engineering Teachers

THE Society for the Promotion of Engineering Education announces that a summer school for engineering teachers will be established and the first sessions held during the coming summer. The Carnegie Corporation of New York has appropriated funds to operate the school for one year.

The establishment of the school is an outgrowth of the extensive investigation of engineering education which the society has been conducting for the past three years. The project was suggested by W. E. Wickenden, director of the society's investigation, as a result of his study of a similar school conducted in England. The project has been studied by the society's Committee on Teaching Personnel, under the chairmanship of Dean Charles H. Warren of the Sheffield Scientific School of Yale University, and was for-

mally recommended by that committee as a project which should be undertaken at as early a date as possible.

Two sessions of the school, each of approximately three weeks' duration, will be held during the first year. Cornell University and the University of Wisconsin have been tentatively selected as sites, and negotiations opened with the authorities of those institutions. It is expected that tuition charges will be limited to a nominal registration fee, and that costs of meals and rooms will be quite low.

The work of the school will center around the teaching of particular subjects of the engineering curriculum. The teaching of mechanics has been selected for the first sessions since that subject is fundamental to all branches of engineering. The work will be divided into three principal divisions: (*a*) The teaching of pure mechanics (analytic mechanics); (*b*) The teaching of the applications of mechanics in related fields; and (*c*) The exposition of methods of teaching in general.

Morning sessions will be devoted to lectures, demonstrations, and laboratory exercises designed to illustrate methods of presenting particular divisions of the subject. The organization, content, and scope of courses in mechanics will be discussed. Methods of teaching will be presented partly by precept and example and partly by lectures devoted to teaching methods in general. Afternoon sessions will be devoted to group discussions and to analyses of the work of the mornings. Evenings will be devoted to lectures on general topics relating to engineering education and to recreation. The teaching staff will be selected from among the foremost teachers of the engineering colleges, and from among the faculties of teachers' colleges and departments of education of the universities.

The bringing of groups of the ablest and most promising younger teachers into contact with leaders having different points of view and different methods of presentation, with adequate opportunity for free discussion, promises a forward step in the teaching of the basic subject of the engineering curriculum. The undertaking, which virtually brings the school to the instructor, and assembles for his benefit a staff of the leading teachers of engineering and of educational method, may prove of significance in the general field of higher education for the professions.

Industry and Education

THE educational work of the Westinghouse Electric and Manufacturing Company at East Pittsburgh, under the direction of C. S. Coler, has attracted much attention as a method of supplying to college graduates that crystallization and extension of their fundamental training necessary in its application to the problems of a large industrial organization. It is gratifying, therefore, to read the announcement which comes from this company that it has entered into an agreement with the University of Pittsburgh whereby a system of educational reciprocity is to give Westinghouse employees who are graduates of approved schools or universities credit toward a degree of M.S. or Ph.D. for work carried on with the company.

The basis of the course is practical experience, which is supplemented by classroom instruction by members of the Westinghouse engineering staff and the University faculty. Westinghouse employees whose registration for the course has been approved will be given fifteen resident university credits for work done with the Westinghouse Company. Since at least twenty-four resident credits are required for any degree at the University, a minimum of nine credits must be obtained in scholastic work at the night school. A study of the announcement issued by the University of Pittsburgh reveals that advanced courses in theoretical and applied subjects are taught by Westinghouse engineers who are given appointments as lecturers in the graduate school, while the more general and fundamental sciences—physics, chemistry, mathematics, etc.—in which advance work is offered, are taught by members of the University faculty.

In further explanation of the nature of the courses offered, Mr. Coler writes as follows:

> The men who will ultimately take up the more technical phases of engineering work such as research, design, and application engineering, are given three months of full-time study under the direct supervision of certain of our more advanced engineers. This course is particularly concerned with the fundamental problems of application and includes work on the following subjects: Materials, D.C. Generators and Motors, D.C. Railway Motors, A.C. Railway Motors, Induction Motors, Insulation and Heating Apparatus, Radio, Switchboards, Industrial and Railway Control, A.C. Generators, Transformers, Synchronous Converters, Lighting, Fan Motors, Regulators and Meters.
>
> Fully half of the time is devoted to broad fundamental considerations, the remainder being devoted more particularly to specific applications of equipment to actual situations.
>
> Dr. Sieg, in charge of the Graduate School of the University of Pittsburgh, after making a very careful study of this course, offers five hours of credit toward the advanced degree for those who successfully complete it in line with our coöperative arrangement.
>
> A still further restricted group of men are selected for our Design School. This course covers a period of full-time instruction under the direct supervision of our more advanced engineers for a period of six months. The course is absolutely fundamental in nature, covering advanced mathematics, physics, mechanical and electrical engineering, and physical metallurgy.
>
> The Graduate School of the University of Pittsburgh will give ten hours of credit for students who successfully complete the course.
>
> The work for which the Graduate School gives credit is of classroom nature rather than shop experience, although certain shop experience is required of each of our graduate students for which no credit is given by the University.

At the University, those chiefly responsible for the University-Westinghouse agreement are Chancellor John G. Bowman, Dr. Leé Paul Sieg, Dean of the Graduate School, and Dr. Frederick Lendall Bishop, Dean of the School of Engineering and Mines.

This significant extension of the so-called coöperative idea in engineering education to candidates for the higher academic degrees serves a twofold purpose in so far as the student is concerned. Not only is he doing advanced academic work, under ideal surroundings of theoretical and practical balance, thereby spending the transition period between school and industry in an organized adaptation to a new environment, but he does this with a gratifying sense of economic independence and justification, often lacking in graduate courses of study, because he is gainfully employed during his course of study and because his employers know and approve of this expenditure of his energies.

Whatever selfish and hard-headed motive of building for the future may have prompted the Westinghouse Company to enter upon this educational policy, the benefit to the young engineers in their employ is none the less real, and the significance of the step as a development of engineering education none the less important. The success of the scheme from all points of view will be watched with interest by educators and industrialists, and should lead to much merited imitation in localities where notable schools and industries exist.

Engineering Foundation Completes Twelfth Year of Service

THE Report of the Engineering Foundation for the year ending February 17, 1927, gives the Arch Dam Investigation as the most prominent among the projects assisted in the previous twelvemonth. This investigation, which has attracted some popular interest as well as international attention among engineers, continues to progress satisfactorily. During the year the Foundation also undertook to assist in financing the final stage of the project started more than three years ago under the auspices of the Society for the Promotion of Engineering Education and the Founder Societies to improve engineering education. This assistance took the form of putting into practical use the knowledge gathered during the three-year investigation in which more than a hundred engineering colleges and societies collaborated.

Fundamental researches in blast-furnace slags at the University of Wisconsin and in dielectric absorption at Johns Hopkins University were aided financially for the first time.

The Foundation also made it possible to continue previously initiated experimental studies on the fatigue of metals, concrete arches, steel columns, lubrication, steam, strength of gear teeth, bearing metals, welding, wood finishing, and personnel.

The financial report shows an income from all sources during the calendar year 1926 of $29,574.68; total funds available, including balance from 1925, of $68,828.46 and total expenditures for all purposes of $38,557.04. Of the expenditures, $25,087 was devoted to research projects, $8751 to the promotion of research, and $4719.04 to administrative expenses.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Oil and Fluid Flow and Heat Transfer in Pipes

DESCRIPTIVE BIBLIOGRAPHY ON OIL AND FLUID FLOW AND HEAT TRANSFER IN PIPES. By Joe B. Butler. Technical Series Bulletin, Missouri School of Mines, Rolla, Mo. Paper, 6 × 9 in., 62 pp.

THIS bulletin lists and describes 370 references to published articles and books. The references are arranged chronologically as to year of publication, are fully cross-referenced, and are indexed as to subject, author, and periodical. A short article on the flow of oil in pipes gives formulas, data, and procedure in solving problems.

All articles with data on friction loss and heat transfer in oil flow are included. Of the articles on flow and heat transfer in pipes of water, air, steam, and gases, only those with data pertaining to fluids in general are listed. Articles on critical velocity, viscosity, and viscosimetry are included if they have applications to oil or fluid flow in pipes.

In 1914, Stanton and Pannell experimentally established for fluid flow in pipes that the friction factor in the ordinary hydraulic formulas is a function of the ratio of the inside diameter of the pipe times the average velocity of flow times the specific gravity of the fluid divided by the absolute viscosity of the fluid. Curves showing this relation over both the streamline and turbulent régimes of flow are plotted from experimental data on water, air, oil, and steam. The author lists 51 references having data or curves applicable to oil over both régimes of flow.

Copies of this bulletin may be obtained by writing to the librarian of the Missouri School of Mines, or to the author, who is associate professor of civil engineering at that institution.

Elements of Heat-Power Engineering

ELEMENTS OF HEAT-POWER ENGINEERING.—Vol. 1, Thermodynamics and Prime Movers. By William N. Barnard, Frank O. Ellenwood, and Clarence F. Hirshfeld. Third edition. John Wiley & Sons, New York, 1926. Cloth, 6 × 9 in., 493 pp., illus., diagrams, tables $4.50.

IN 1912 the first edition of Elements of Heat-Power Engineering, by Hirshfeld and Barnard, appeared in one volume, bringing together the theory of thermodynamics and its application. This book passed to its second edition in 1915, and in September last the first volume of the two-volume third edition, completely rewritten by Professors Ellenwood and Barnard, was issued. This first volume includes the cycles, operation, and performance of air compressors, internal-combustion engines, vapor engines, and steam engines, as well as the thermodynamics of gases and vapors, merely touching the principles of steam turbines. The more detailed discussion of the turbine will probably be considered in the second volume, together with such topics as fuels, combustion, heat transfer, boilers, superheaters, gas producers, waste heat, feedwater heaters, condensers, refrigeration, and the economics of selection of equipment.

This excellent text is intended for practicing engineers as well as for students in engineering schools.

After developing the fundamental relations of energy, power, work, and heat and their units, an historical outline with modern applications gives a background to this study. The important ideas of the energy equation, reversibility, availability, and entropy are discussed in general before a more specific application is made to gases and their thermodynamic processes. The study of gases is then applied to air compressors, air engines, and internal-combustion engines and to their operation. The study of the properties and processes of vapors is followed by the application to engines and turbines.

The authors make a clear distinction between the analysis and the efficiency of the vapor cycle and of the engine cycle. In the temperature-entropy or the pressure-volume diagram, the curves of boiler feeding and heating are clearly indicated. They make especially clear the principles of reheating, throttling, regeneration, and the expansive use of steam, analyzing these features of modern power-plant operation. These and the use of binary-vapor cycles are illustrated by temperature-entropy diagrams and diagrams of apparatus showing relative positions of the different devices in these installations.

Each theoretic discussion of an application is followed by sections describing the actual forms of apparatus and their details or parts. Governors, methods of governing, engine details, ignition systems, carburetors, and instruments are covered at proper parts of the text.

In discussing the internal-combustion engine, not only are air standards used, but the real mixture is considered and its effects shown. The Brayton cycle, the dual-combustion cycle, and the Walker cycle are considered after the discussion of the Otto and Diesel cycles. The hot-air cycles of Stirling and Ericsson are discussed in this chapter.

The chapters on the properties of vapors and on thermodynamic processes of vapors are especially helpful.

ARTHUR M. GREENE, JR.[1]

James Watt and the Steam Engine

MEMBERS of the Society who in 1910 had the rare privilege of meeting with the Institution of Mechanical Engineers in Birmingham will also remember vividly the visit to Watt's home and to his workshop.

Watt is the synonym of Mechanical Engineering, and members will be interested to learn that an important work under the above title is to be published shortly, by the Oxford University Press, England.

In 1919, when the centenary of the death of James Watt was commemorated, it was decided by the Watt Memorial Committee in Birmingham to publish a memorial volume. This was undertaken in collaboration by H. W. Dickinson and Rhys Jenkins. The former is at the Science Museum, South Kensington, London, and the latter was recently at the British Patent Office. Both are members of the Institution of Mechanical Engineers, England, and of the Newcomen Society for the Study of the History of Engineering and Technology.

The volume is a critical study based on a first-hand examination of hitherto untouched sources of information as well as of the known sources. The first part is biographical and deals with

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James Watt as a man; the second and longer part deals with the development of the steam engine under his hands, and it is upon this development that much new light is shed. The book will be found to be an inspiration to engineers.

The volume will be a sumptuous one, format 11¼ in. by 8¾ in., with a photogravure frontispiece from a hitherto unpublished portrait; it will contain 12 collotype plates, 90 more in halftone, and 42 line illustrations, most of these being taken from original drawings preserved at Birmingham. In addition there will be two maps. The price to subscribers post free on the American continent will be $10.20. Those acquainted with book production will infer from the foregoing particulars that the book is to be published below cost; this is the case, for the Memorial Committee set aside $2425 for its preparation and the authors give their services. The price, it should be noted, will be raised on publication.

On page 142 of the Advertising Section will be found a subscription blank.

A.E.S. Library Report

IN PRESENTING the Annual Report of the Library Board for the year 1926, the Director, Harrison W. Craver, pointed out that although it had been a year devoid of unusual events since the Library is now adequately catalogued and competently staffed, nevertheless it was easy to see many new forms of useful work which might be undertaken when larger funds became available; for example, there was a great need for a complete index to periodical literature.

At the close of the year the Library had on its shelves 103,903 volumes, 3055 pamphlets, 1950 maps, and 4227 searches, giving a total of 113,135 items. During the year the additions were 4097 volumes, 845 pamphlets, 150 maps, and 107 searches, a total of 5199.

The Library was used during 1926 by over thirty-three thousand persons, a number equaling about 63 per cent of the membership of the Founder Societies. Of these 22,488 visited the Library, the remainder making their inquiries by mail or telephone. The inquiries by telephone numbered 5911, an increase of thirty per cent over 1925. Two hundred and sixty-nine searches and one hundred and eighty-three translations were made. The calls upon the photoprinting equipment were 20 per cent greater than the previous year.

The Library, Director Craver said, was administered to provide the most efficient service possible to the profession so far as the needs had been ascertained and so far as funds to meet these needs were available.

Books Received in the Library

ABWÄRMEVERWERTUNG ZUR HEIZUNG UND KRAFTERZEUGUNG. By Hans Balcke. V.D.I. Verlag, Berlin, 1926. Cloth, 4 × 6 in., 208 pp., illus., diagrams, tables, 4.80 mk.

A brief discussion of the utilization of waste heat for heating and for power production. The author discusses the sources of waste heat, the proper lines for its utilization, and the elements of the plants for this purpose. The treatment, though condensed, is thoroughly practical, and the book is intended as a pocketbook for the engineer.

AERIAL CABLEWAYS. By G. Ceretti. E. & F. N. Spon, London; Spon & Chamberlain, New York, 1927. Boards, 4 × 7 in., 111 pp., illus., diagrams, tables, 5s.

A brief collection of formulas, tables, and practical observations, prepared by the principal of an important firm of Italian cableway builders.

AMERIKAS DAMPFTURBINENBAU. By E. A. Kraft. V.D.I. Verlag, Berlin, 1927. Cloth, 8 × 11 in., 116 pp., illus., 14 r.m.

An interesting report upon a tour of inspection and study of the American steam-turbine industry, in which the author compares the designs of the principal American turbines with those of Europe and describes rather fully American methods of manufacture. Efficiency is the main object of the European builder, says Dr. Kraft; reliability, that of the American. Each land can learn from the other.

ANCIENT EGYPTIAN METALLURGY. By Major H. Garland and C. O. Bannister. Charles Griffin & Co., London, 1927. Cloth, 5 × 8 in., 214 pp., illus., portrait, 12s. 6d.

Major Garland was for many years Superintendent of Laboratories at the "Citadel," Cairo, during which time he had unusual opportunities to collect and examine ancient specimens of metals. Unfortunately, his death prevented him from publishing an account of his investigations. His notes and memoranda have, however, been arranged for publication by Mr. Bannister. They treat of the sources from which ancient Egypt obtained metals, of its bronze industry, of the iron age in Egypt, and of ancient Egyptian tools. A chapter is devoted to Major Garland's metallographic investigations of antique metals and his conclusions from them.

DIE AUSKLEIDUNG VON DRUCKSTOLLEN UND DRUCKSCHÄCHTEN. By Otto Walch. Julius Springer, Berlin, 1926. Paper, 7 × 10 in., 188 pp., illus., diagrams, plates, 19.50 r.m.

A review of present practice in lining pressure shafts and tunnels, accompanied by a discussion of the theoretical conclusions drawn from experience. The author discusses the forces generated and their action, the determination of these forces and of the loss of water. He describes the methods of lining adopted in many pressure tunnels, discusses their efficiency, and gives recommendations of a practical nature.

BERECHNUNG DER WASSERSPIEGELLAGE. By Paul Böss. V.D.I. Verlag, Berlin, 1927. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, heft 284.) Paper, 8 × 11 in., 96 pp., illus., diagrams, plates, 7.50 r.m.

An investigation of the effect of variations in flow upon the surface of streams. The author bases his study upon Bernoulli's theorem and the energy curve and considers cases both of regular flow and of intermittent flow. Among the questions considered are the effects of changes in the slope or roughness of the channels, of enlargements or contractions caused by piers, changes in the elevation of the bed or by weirs, by hydraulic jump, and by the artificial increase of influx or efflux. A method of calculation is presented with the results of experiments at the hydraulic laboratory of the Karlsruhe Technical Institute.

CENTRIFUGAL PUMPS, Their Design, Operation, and Testing. By George Higgins. Crosby Lockwood & Son, London, 1926. Cloth, 6 × 9 in., 86 pp., illus., diagrams, plates, 9s. 6d.

This book sets forth the theory of the centrifugal pump and explains the method of design, step by step. The method is illustrated by two examples. Location and operation are also discussed briefly. The author treats principally of pumps without guide vanes. The work is a concise account of the methods used by a practical designer.

COMMERCIAL AIR TRANSPORT. By Lt-Col. Ivo Edwards and F. Tymms. Isaac Pitman & Sons, New York, 1926. Cloth, 6 × 9 in., 163 pp., illus., map, $2.50.

This little book, setting forth the basic principles of the operation of air-transport lines and the ways in which development and progress are likely to occur, is intended primarily as a textbook for those preparing for membership in the British Institute of Transport. The author discusses subsidies, the relative advantages of state and private operation, the economics of the problem, ground organization, traffic control, routes, passengers, freights, mails, and a variety of other matters connected with the question.

ECONOMIC BASIS OF FAIR WAGES. By Jacob D. Cox, Jr. Ronald Press Co., New York, 1926. Cloth, 6 × 9 in., 139 pp., diagrams, $3.50.

A brief discussion of the economic theory of wages, of the factors that determine money wages, of the laws of prices and of real wages, and of the question of fair wages. The object is to present the fundamentals upon which wages must be based, in order to be fair to both worker and employer.

DIE EIGENSCHAFTEN ELEKTROTECHNISCHER ISOLIERMATERIALEN IN GRAPHISCHEN DARSTELLUNGEN. By U. Retzow. Julius Springer, Berlin, 1927. Boards, 6 × 9 in., 250 pp., graphs, 24 r.m.

The contents of this book are unusual. The first half consists of three hundred and thirty graphic charts which show the electrical, physical, and mechanical properties of the insulating mate-

rials used industrially. The second half gives an exhaustive bibliography on insulating materials, containing some three thousand references. Except for a brief introduction, the author has provided no text. The source of each chart is clearly indicated and references are also given to the other publications upon the subject. The book brings together a great amount of scattered information, and should prove of great assistance to all who have to do with the design and construction of electrical apparatus.

FACTORY MANAGEMENT. By Paul M. Atkins. Prentice-Hall, New York, 1926. Cloth, 6 × 9 in., 386 pp., illus., forms, $5.

An introduction to the study of manufacturing administration, intended for those who have had a general course in business administration. The problem is approached from a practical point of view, and the control of production is emphasized as a major function of business administration. Such matters as materials, equipment, plant layout, standards, scheduling, tools, inspection, and storing are discussed and good practice illustrated.

DER FLOTATIONS-PROZESS. By C. Bruchhold. Julius Springer, Berlin, 1927. Cloth, 6 × 9 in., 288 pp., illus., diagrams, 27 r.m.

Intended as a handbook of flotation for those operating flotation plants. The author has therefore confined himself to recent ideas and to a full account of the methods in use today, omitting the older processes, which have only historic interest. The book contains much information upon methods, machinery, and operation brought together in convenient form.

GASOLINE AUTOMOBILE. Vol. 1, The Gasoline Engine. Seventh edition. By P. M. Heldt. P. M. Heldt, Nyack, N. Y., 1926. Cloth, 6 × 9 in., 728 pp., illus., diagrams, $8.

The treatise of which this forms the first part is one of the very few in the English language that considers the automobile from the point of view of the designer and manufacturer, rather than of the owner and repairer. Since 1911, seven editions have appeared, as well as French and German translations.

The new edition has been entirely reset and largely rewritten. There is also a considerable increase in size, and most of the illustrations and plates are new. The chapters dealing with the principal parts of the engine, with engine characteristics, and with engine tests have been rewritten, and a chapter on heavy-oil engines has been added.

The book discusses the principles underlying the design of automobile engines and the practices followed. Special attention is paid to the relation between design and methods of manufacture.

DIE GRUNDLAGEN DER WÄRMEÜBERTRAGUNG. By Friedrich Merkel. Theodor Steinkopff, Dresden and Leipzig, 1927. (Wärmelehre und Wärmewirtschaft, bd. 4.) Paper, 6 × 9 in., 234 pp., diagrams, tables, 13.50 r.m.

This monograph brings together the existing theoretical and experimental investigations of heat transmission in connected form, with special emphasis upon their practical applications.

The first of the five sections of the book discusses the physical laws that govern conduction in solids, especially in plates and cylinders. Section two treats of heat transmission by conduction and convection, including the theory of the action of the combined methods and the results of experimental investigations. This section is much the largest in the book. Section three is devoted to radiation, and section four to heat transfer through walls. Section five contains such data as the specific gravity, specific heat, and conductivity of the more important solids, liquids, and gases.

INTRODUCTION TO CONTEMPORARY PHYSICS. By Karl K. Darrow. D. Van Nostrand Co., N. Y., 1926. Cloth, 6 × 9 in., 453 pp., diagrams, $6.

This volume includes, in a more systematic development, the substance of a series of articles which appeared in the Bell System Technical Journal under the title, Some Contemporary Advances in Physics, together with much additional matter. Dr. Darrow's object is a unified account of the phenomena that the nuclear-atom model of Rutherford and Bohr is intended to interpret, such as the directly perceived properties of electrons and ions, the detachment of electrons from atoms, the deflections of flying charged particles by atoms, the transfer of energy from electrons and radiation to atoms, and the regularities of line spectra and band spectra.

JOURNAL OF THE ROYAL TECHNICAL COLLEGE. No. 3, December, 1926. Glasgow, 1926. Paper, 7 × 10 in., 180 pp., 10s. 6d.

This number of the Journal describes some of the researches carried out at the College. Those of special interest to engineers include studies of the overstraining of steel by tension, a simple method of comparing heat-insulating materials, the passage of electricity through dilute solutions, the overheating of mild steel, and some physical properties of duralumin.

KINETIC THEORY OF GASES. By Leonard B. Loeb. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 555 pp., $5.50.

Professor Loeb has endeavored to fill the need for a textbook upon modern kinetic theory which is not too abstruse for the average college student and which will serve as preparation for more advanced writings. He begins with a concise presentation of the various concepts and classical derivations of the kinetic theory for third-year college students, and then proceeds on toward the needs of advanced students and investigators for a convenient, more elaborate account of the phenomena in question.

THE LIGHTNING GRAPHS. Series 1, General. By I. S. Dalgleish. Crosby Lockwood & Son, London, 1926. Cloth, 7 × 10 in., 12 pp., 10 graphs, 5s.

The first instalment of a collection of nomographic charts intended to assist in frequently recurring calculations that cannot be solved readily with a slide rule. The charts given in this volume enable the unknown variables in the three equations: $a^2 = b^2 + c^2$, $a^n = d$, and $\sqrt[m]{a} = d$, to be found directly to within one-half of one per cent. These equations cover the relationship between the sides of a right-angled triangle, and give values of hyperbolic logarithms and reciprocals of all numbers.

MANUFACTURE OF PULP AND PAPER. Vol. 3. Second edition. By Joint Executive Committee of the Vocational Education Committees of the Pulp and Paper Industry. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., various paging, illus., tables, $5.

A comprehensive work upon the manufacture of wood pulp, prepared by a number of specialists for the Canadian Pulp and Paper Association and the Technical Association of the Pulp and Paper Industry. The book is intended primarily for use as part of a course of vocational study of the paper industry, but is in addition the most satisfactory account of its subject now available in English. This edition includes accounts of developments during the past six years, such as bark presses, automatic grinders, continuous causticizers, pulp washing, and the recovery of fiber from effluents.

MATTER AND GRAVITY IN NEWTON'S PHYSICAL PHILOSOPHY. By A. J. Snow. Oxford University Press, London and New York, 1926. Cloth, 5 × 8 in., 256 pp., $2.50.

This essay, which studies a most important and critical period of natural science, is especially timely at present, when the adequacy of Newtonian mechanics is being questioned. It traces the developments of the atomic theory and attempts to present Newton's conception of the nature and function of atoms. The author presents a study of some of the fundamental concepts of Newton's philosophy, and of the influence upon Newton's views of his predecessors and contemporaries.

MODERNE GRUNDBAUTECHNIK. Vol. 2: Theorie der Tiefschachtgründungen mit der Grundkörpermaschine. By Ottokar Stern. Wilhelm Ernst & Son, Berlin, 1927. Paper, 5 × 8 in., 56 pp., illus., diagrams, 2.70 r.m.

This pamphlet discusses, from a theoretical and a practical point of view, the application of the "compressol" system to deep foundations, foundations under water, etc. The author discusses the dynamics and statics of the problem and gives examples of special applications.

NON-TECHNICAL CHATS ON IRON AND STEEL. By La Verne W. Spring. New edition. Frederick A. Stokes Co., New York, 1927. Cloth, 6 × 9 in., 465 pp., illus., tables, $4.

A popular, readable account of the iron industry, describing the metallurgical and mechanical processes of the blast furnace, steel works, foundry, and rolling mill, and accompanying the text by numerous well-selected photographs. This edition has been revised and enlarged to cover recent changes.